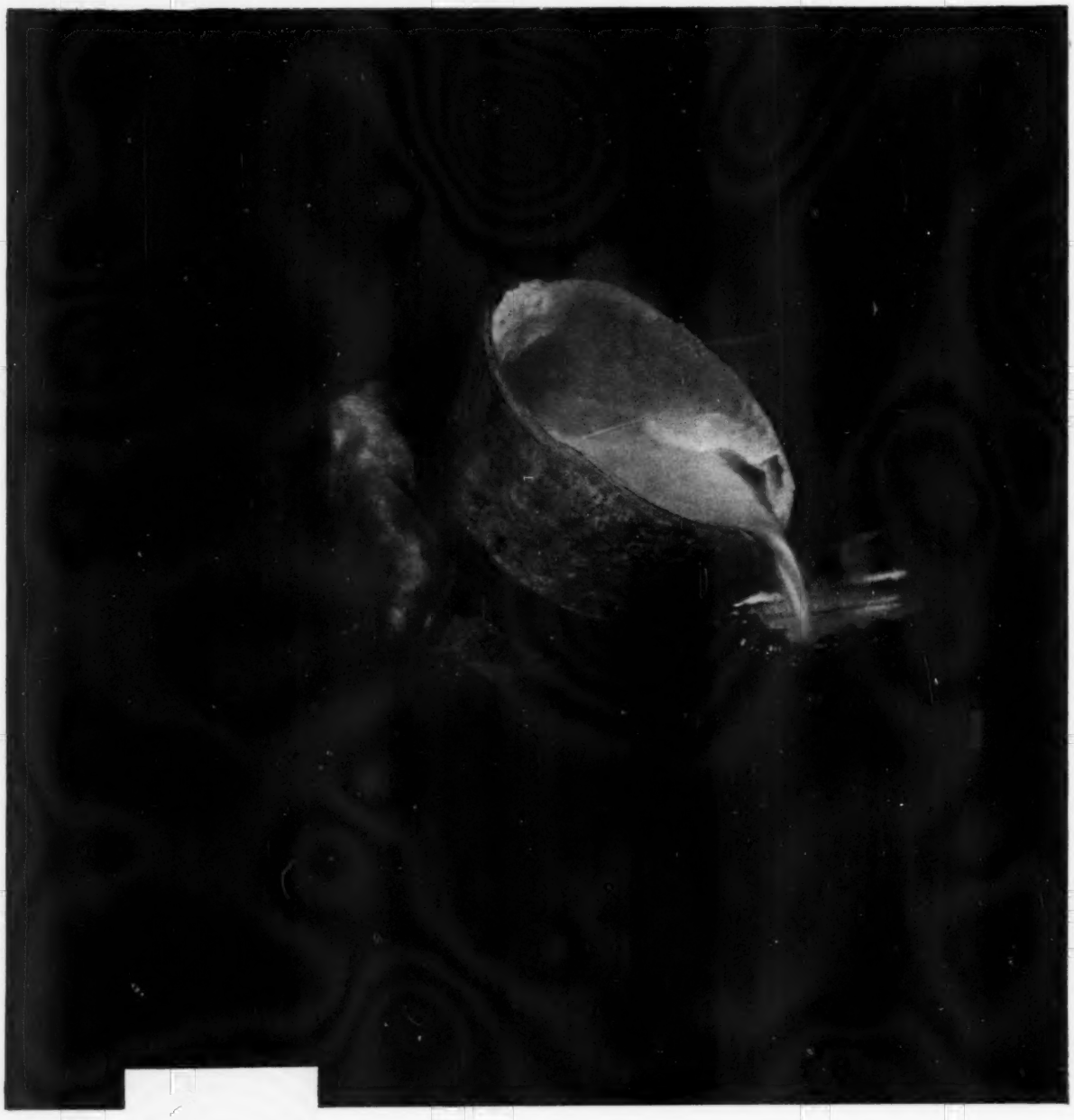
METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 60 No. 362 DECEMBER, 1959 Monthly: Two Shillings and Sixpence



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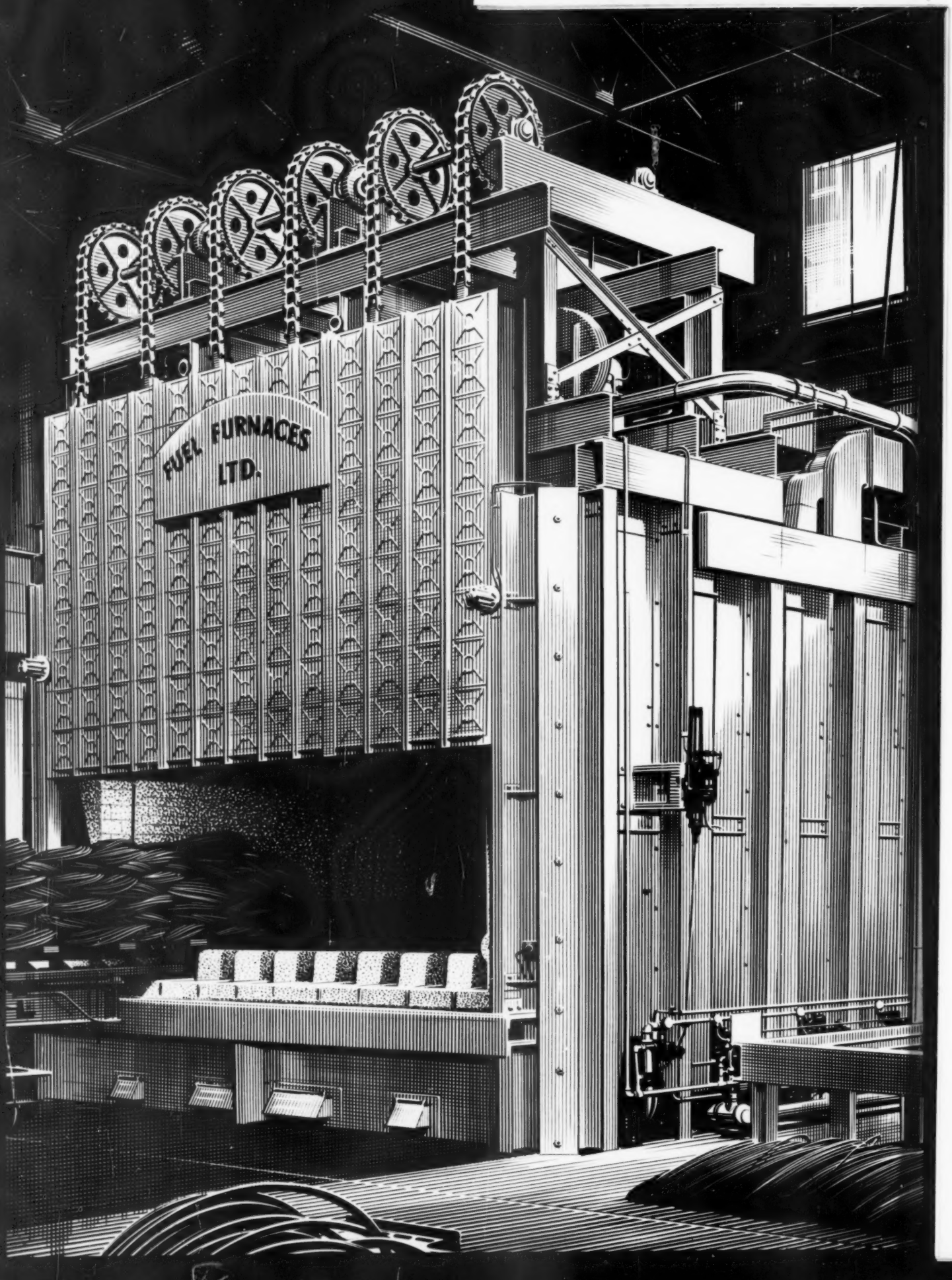
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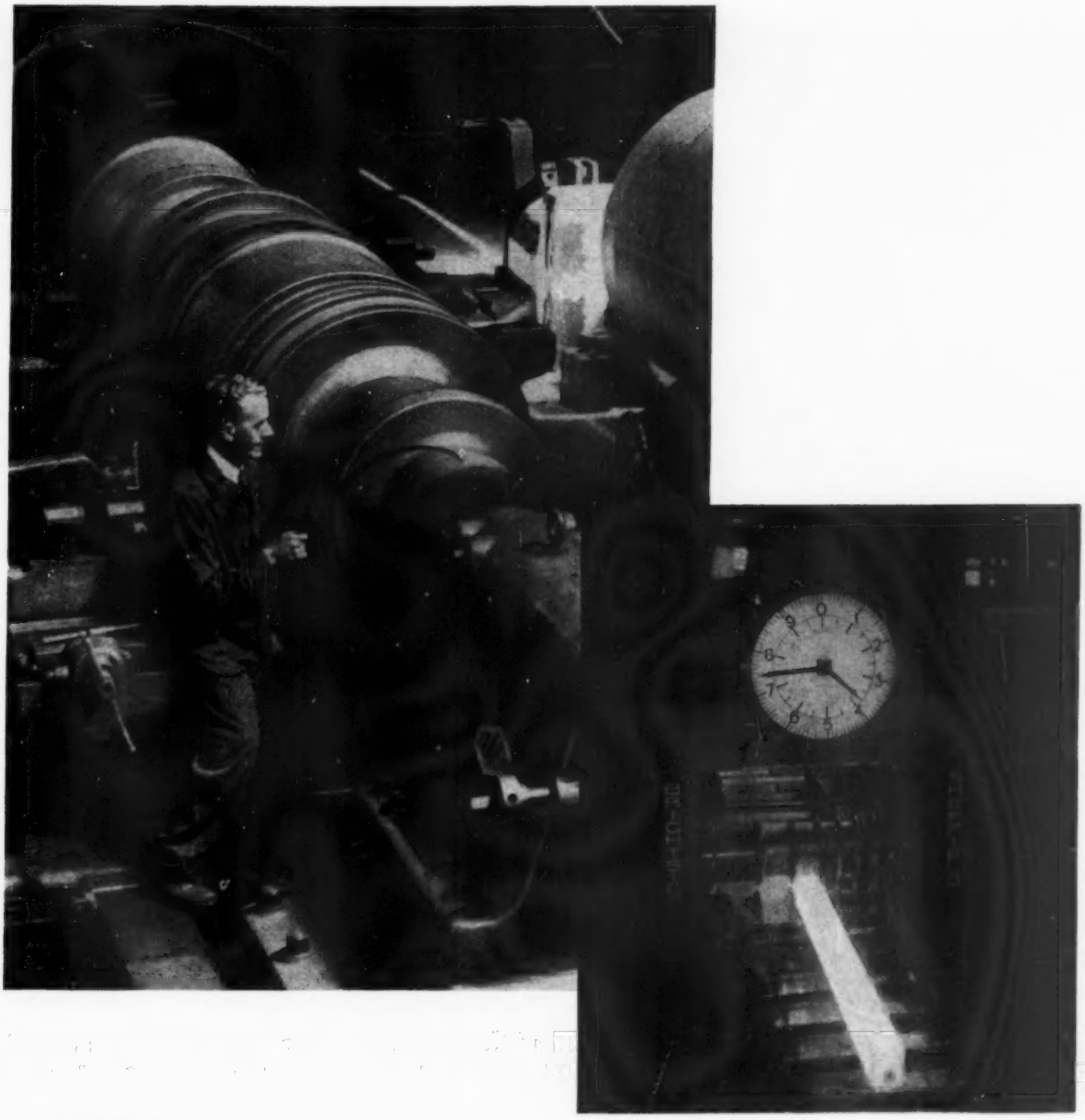

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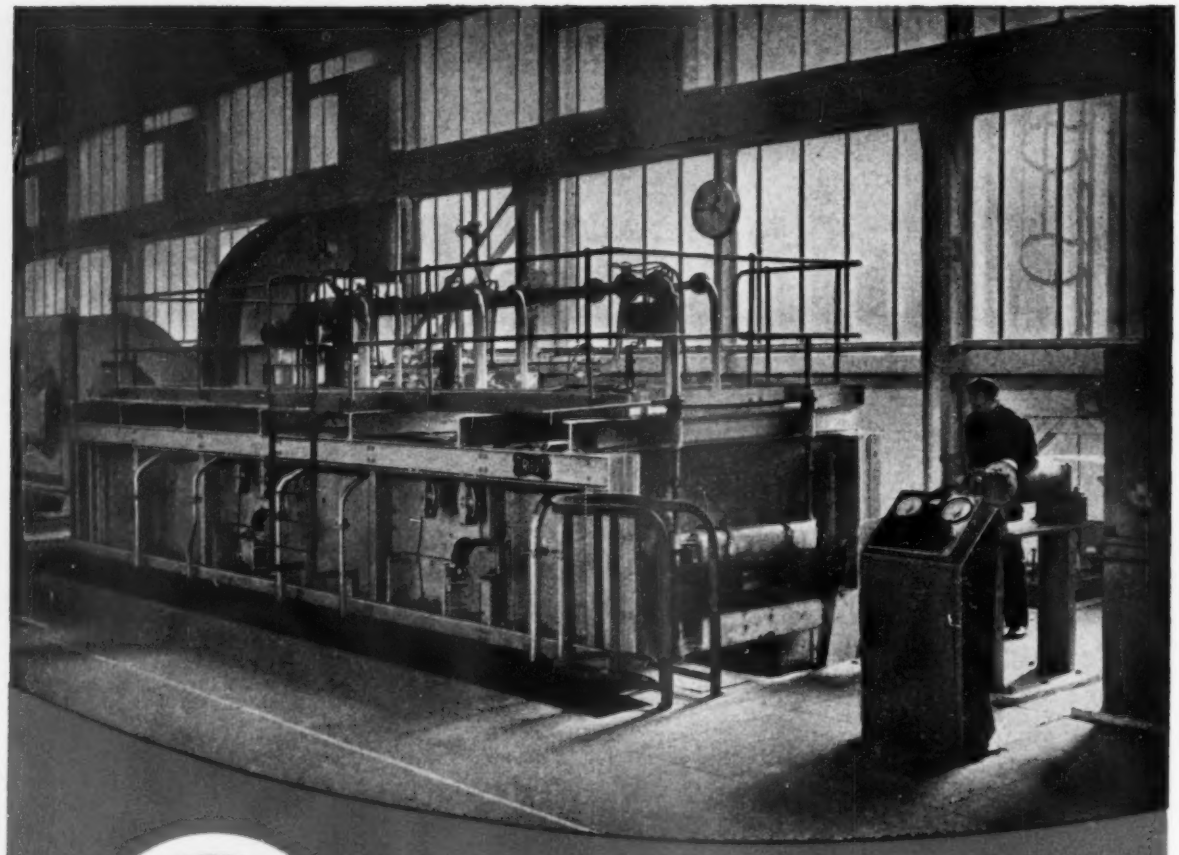

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Stainless Steel Strip Annealing Furnace

The illustration shows a Furnace for continuous treatment of ferritic or austenitic steel strip.

Installed at the Stocksbridge Works of Samuel Fox and Co. Ltd., Sheffield.

We specialise in the design and construction of: Open Hearth Furnaces • Soaking Pits of all types • Continuous Multi-zone Bloom and Slab Re-heating Furnaces • Continuous Bogie type Ingot and Slab Heating Furnaces • Furnaces for Aluminium Melting, Coil Annealing and Slab Re-heating • Forge and Heat Treatment Furnaces • Stress Relieving Furnaces • Shipyard Plate and Bar Furnaces • Modern Lime Burning Kilns

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F144

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Heating Rods for High Temperatures

The high reputation of SILIT Heating Rods
for Electric Furnaces is of many years' standing.
They are remarkable for their limited amount of "ageing"
which is amply covered by a voltage reserve
of only 40% for temperatures up to 1500°C.
A salient feature of the SILIT Heating Rods is that butt joints
between the glowing portion and the connecting ends are avoided.
The thickened ends are formed by tightly fitting sleeves
made of the same material as the rods.

A wide range of Silit Rods of equal diameter throughout can also be supplied, diameters ranging from $\frac{1}{16}$"- $1\frac{3}{4}$".

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The illustration shows the Heat Treatment Plant we recently installed at Messrs. Crowborough Engineering Works Ltd. Aycliffe.

The complete unit installation at Aycliffe consists of Hardening Furnace, two Tempering Furnaces, Water Quench Tank, Oil Quench Tank, Loading and Unloading Racks. The unit is serviced by a fully-automatic, centrally-located, electrically-operated crane. The two re-circulating Tempering Furnaces utilise the waste heat from the Hardening Furnace. Supplementary gas is automatically provided when necessary.

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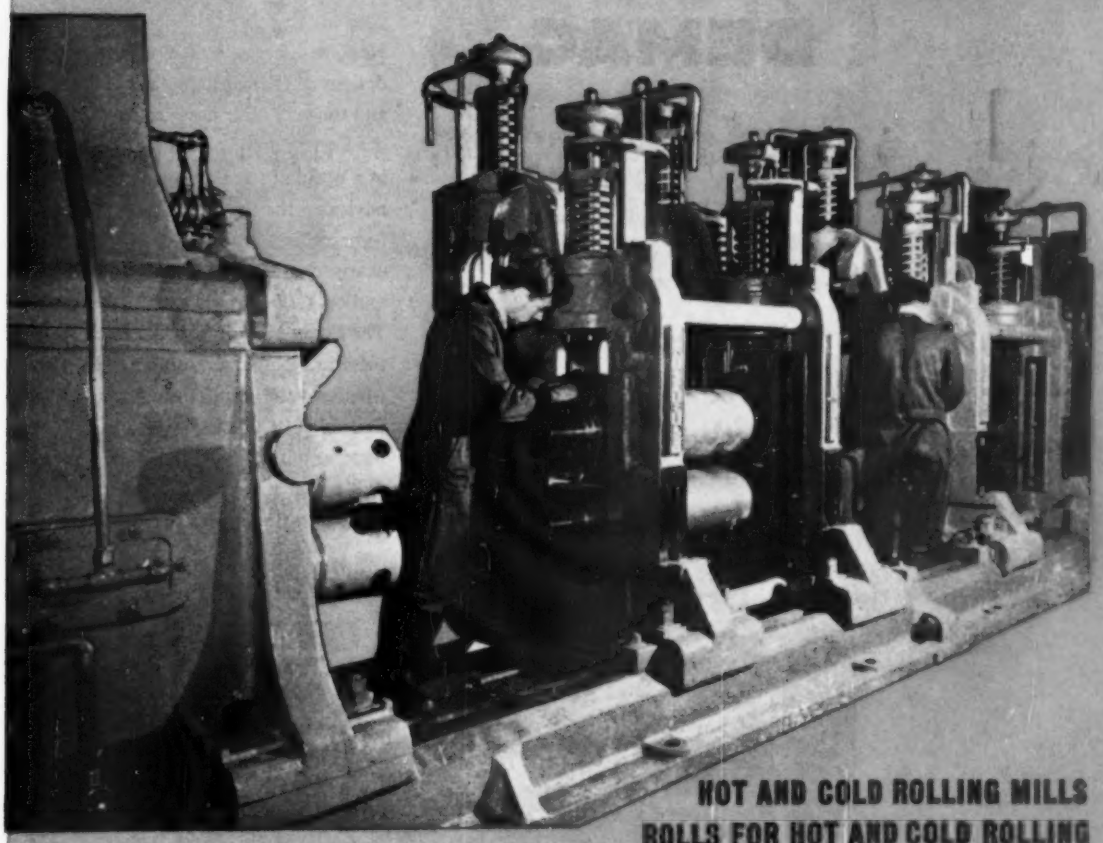

Shop erection photograph of a 10½ in. dia. Double Duo Rolling Mill for the precision rolling of Alloy and Tool Steel Bars and Rods.

HOT AND COLD ROLLING MILLS
ROLLS FOR HOT AND COLD ROLLING
ROLL LATHES
HOT AND COLD SHEARS
HOT SAWS AND REELERS
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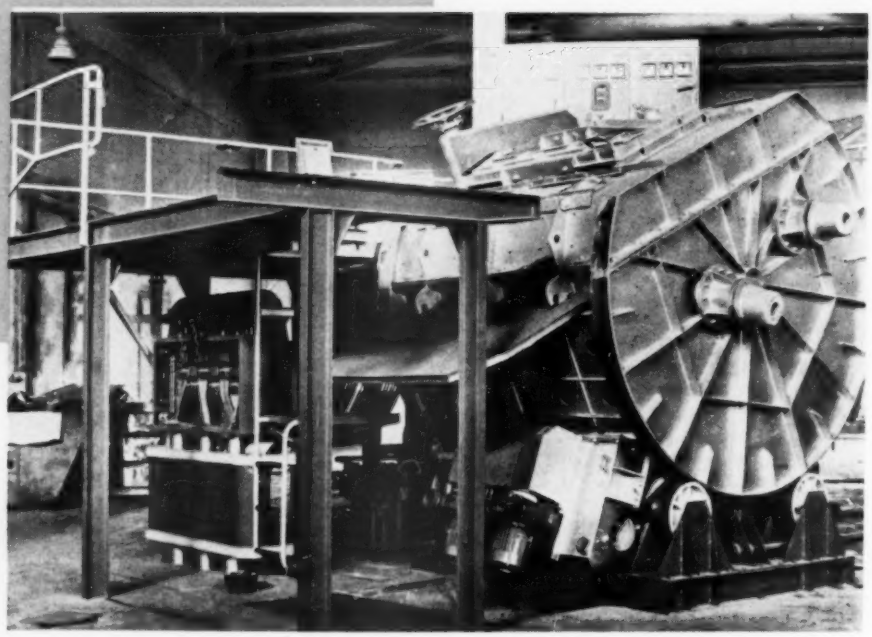
for non-ferrous metals

The melting of copper and copper alloys, zinc and light metals by the electric induction method could well solve your melting problems.
Now, with access to the proved designs of Demag Induction Melting Plant and the very wide experience of the Demag organisation, G.W.B. are in a position to offer unbiased advice on the choice of the most suitable furnace for your particular charge characteristics, output requirements and operational needs.
The experience of G.W.B. places them in the unique position to assess whether your requirements demand the Crucible or Channel Type, and whether a Mains or Medium frequency unit will give the best service. This advice is without obligation.



Demag Channel Type Induction Melting Furnace for brass, copper alloys and aluminium alloys.

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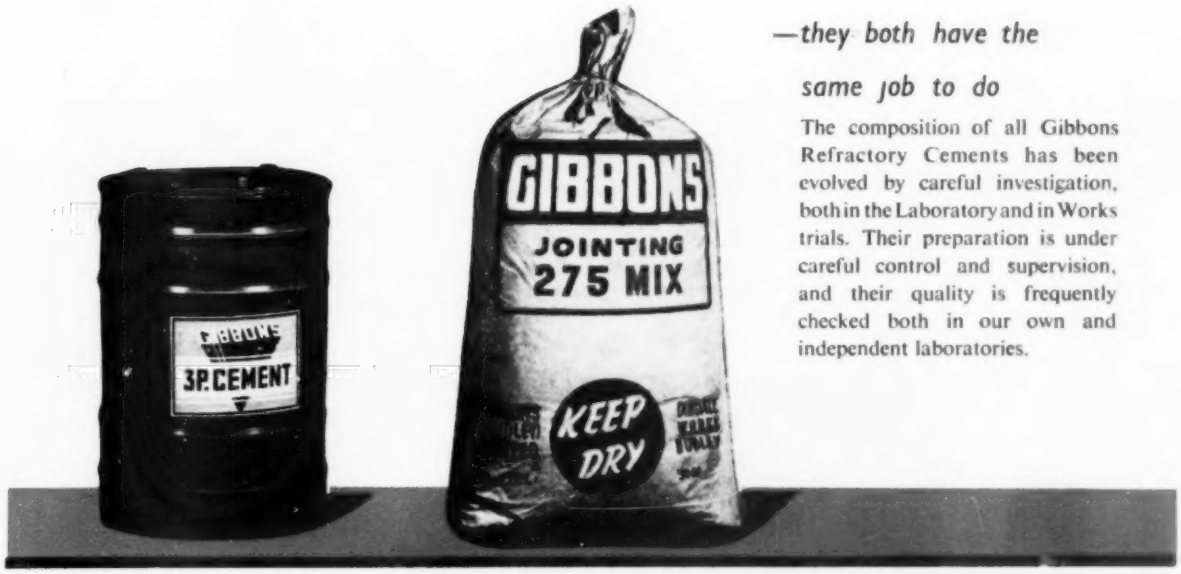
Choose your Refractory Cements as carefully as you choose your bricks



—they both have the same job to do

The composition of all Gibbons Refractory Cements has been evolved by careful investigation, both in the Laboratory and in Works trials. Their preparation is under careful control and supervision, and their quality is frequently checked both in our own and independent laboratories.

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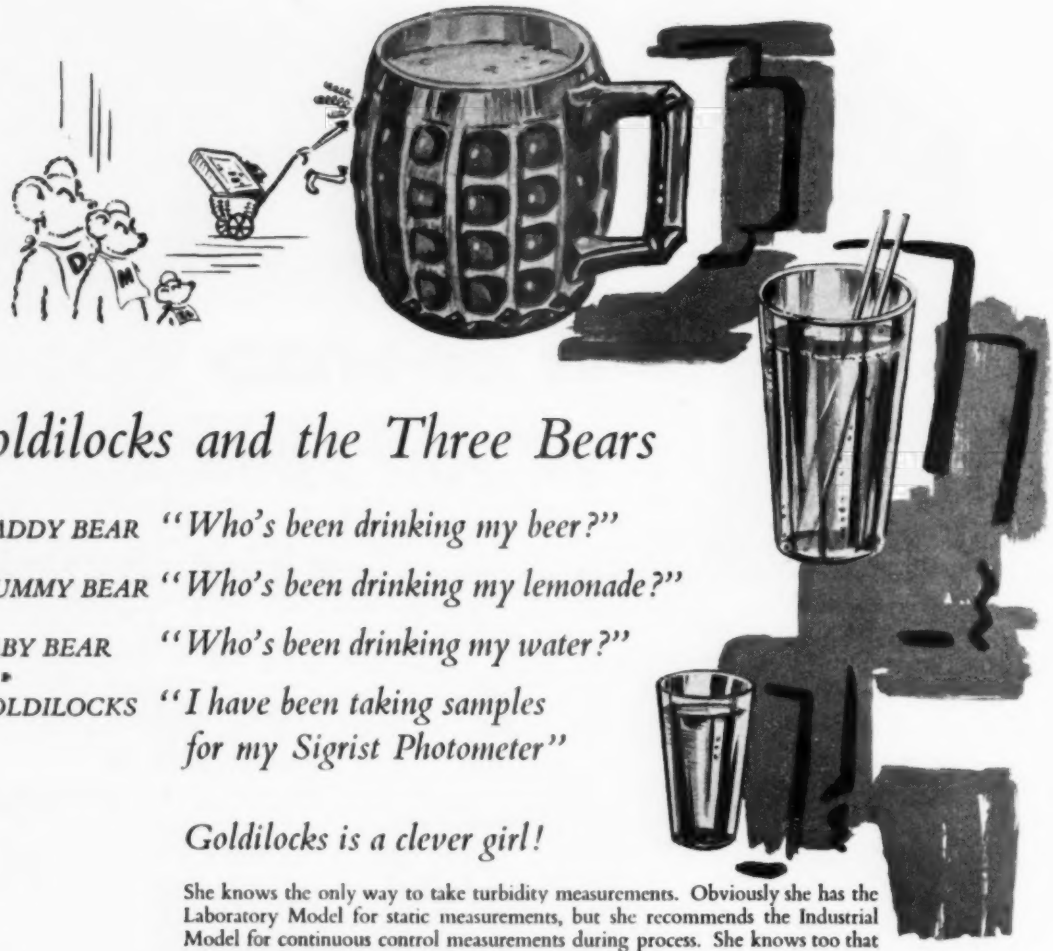


Goldilocks and the Three Bears

DADDY BEAR *"Who's been drinking my beer?"*

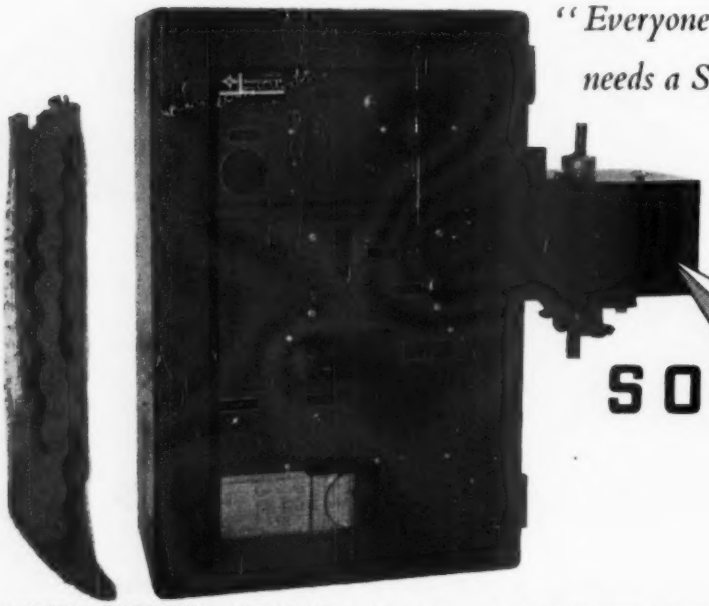
MUMMY BEAR *"Who's been drinking my lemonade?"*

BABY BEAR *"Who's been drinking my water?"*

GOLDILOCKS *"I have been taking samples for my Sigrist Photometer"*

Goldilocks is a clever girl!

She knows the only way to take turbidity measurements. Obviously she has the Laboratory Model for static measurements, but she recommends the Industrial Model for continuous control measurements during process. She knows too that colour measurement and control is just as simple!
Haze: Particles of 0.5 micron and 0.1 p.p.m. concentration.
Colour: Wavelength 366-950 mμ.

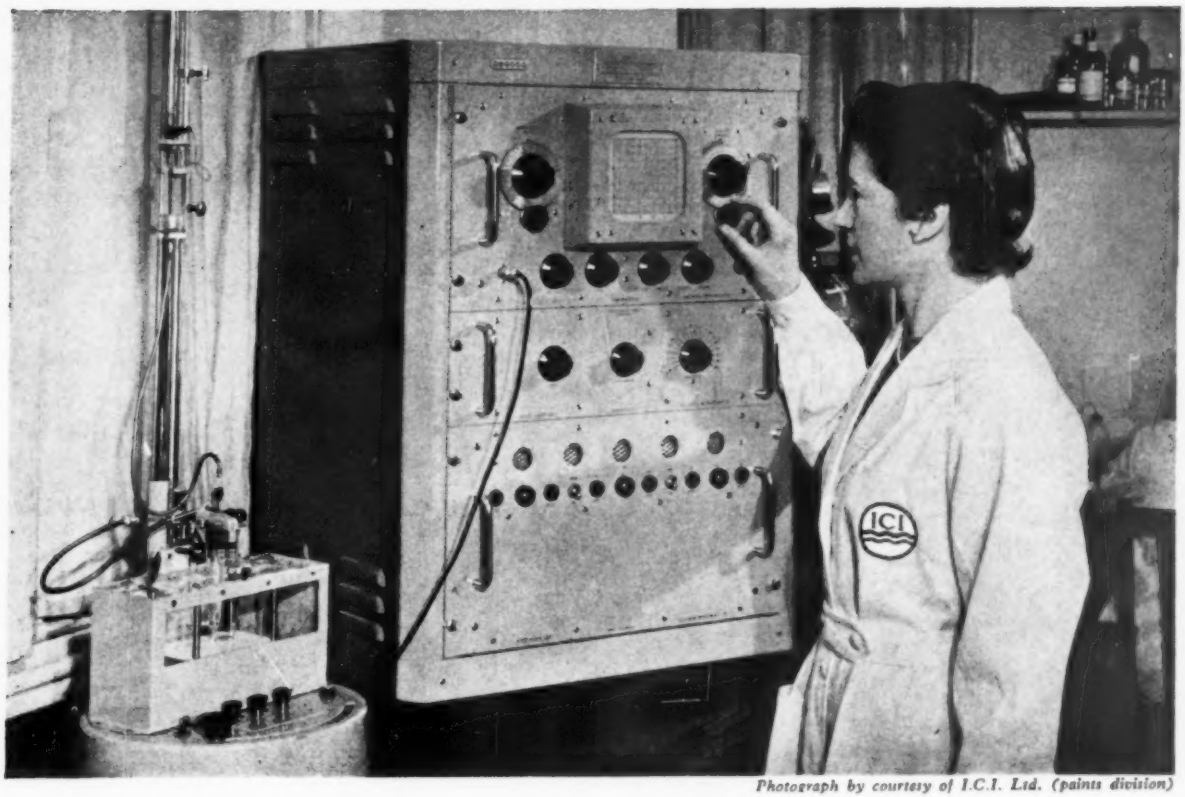


"Everyone interested in clear liquids needs a Sigrist Photometer."

SOUTHERN
Instruments

THE ANALYTICAL INSTRUMENTS DEPARTMENT OF SOUTHERN INSTRUMENTS LIMITED, CAMBERLEY, SURREY. CAMBERLEY, 3401

This is polarography — the easy way!



Photograph by courtesy of I.C.I. Ltd. (paints division)

Analysts all over the world have found how easy it is to get rapid and accurate analyses with our Cathode Ray Polarograph. It is quick in action, gives direct or derivative readings, and has that extra sensitivity you so often require.

Its easily readable peak polarograms repeat every seven seconds. Your laboratory is wasting expensive time without this indispensable instrument.

SPECIFICATION

DISPLAY. six-inch diameter cathode ray tube, with a 9cm. square graticule printed on its flat, long persistence screen.

VOLTAGE SWEEP. Rate: 0.3 volt per second (fixed). Range: 0.5 volt per sweep approximately (fixed). Start Potential: + 0.5 volt to -2.0 volts (variable). Sweep Time : One polarogram per mercury drop with seven second repetition.

PLATE ONE

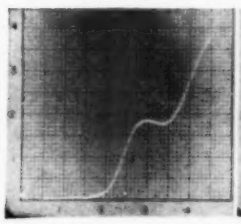
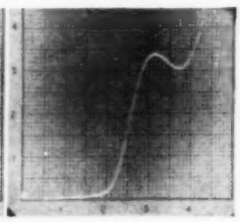


PLATE TWO



TYPICAL APPLICATION FOR CATHODE RAY POLAROGRAPH

Determination of Cyanide in Effluent Sample. Introduce 5 ml. sample into two 10 ml volumetric flasks, into one flask add 0.2 ml. of a standard cyanide solution, (50 µg/ml. CN^-), and make each up to the mark with 0.2N NaOH. Shake well. Transfer 5 ml. from each flask into polarographic cells, and de-aerate with nitrogen for 3 mins. Record the polarograms applying anodic oxidation on start potential –0.4V and scale factor 1.0.

x µg CN^- + 5 µg CN^- = 34 divisions (Plate 2)

x µg CN^- = 18.5 divisions (Plate 1)

$\therefore$ 5 µg CN^- = 15.5 divisions

$$x = \frac{5 \times 18.5}{15.5} \ \mu g$$

$$x = 6.0 \ \mu g$$

Volume of sample in cell = 2.5 ml.

$\therefore$ Concentration of CN^- in sample = 2.4 µg/ml.

Send now for "Trace Techniques" just published containing 30 new polarographic methods. Price 25/- post paid. (U.K. only.)

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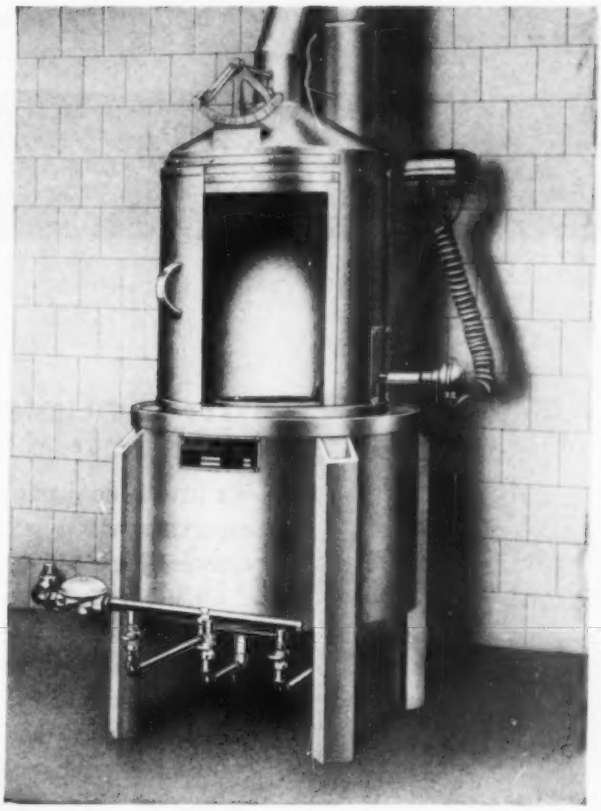
GAS BLAST COMBINED FORGE AND BRAZING HEARTH

Complete with Motor Driven Positive Air Blower, two Gas Blast Blow Pipes and one Gas Blast Burner. Suitable for Tube bending up to 1 in. diameter.

Size of Hearth, 20 in. × 20 in. × 4 in.

Gas Consumption, 200 cu. ft. per hour maximum.



NATURAL DRAUGHT GAS FIRED SALT BATH SUITABLE FOR CYANIDE OR NEUTRAL SALTS

Suitable for temperatures up to 900° C.

Obtainable in the following sizes :
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Time to heat up—1½ hours.

Manufactured by

KASENIT LTD

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Products of BRITISH DRIVER-HARRIS

No. 2 Thermocouple Alloys

We have been making thermocouple alloys at Cheadle for many years. Our experience tells us what people look for and our alloys provide it—stability, constant EMF values and long life.

Different temperature ranges call for different alloy combinations—and we provide them, including 'T1/T2', the only British-made base metal thermocouple for temperatures up to 1100°C. In cases where thermocouple wires are covered by a British Standard we produce them to conform to the Standard.

Accurate temperature measurement and control is something that cannot be left to chance. It is best left to Driver-Harris thermocouple alloys.

T1/T2 are wires of the nickel-chromium/nickel-aluminium type for use at high temperatures and conform to the British Standard Specification 1827: 1952 within the usual tolerances. They also meet the requirements laid down in Air Ministry Specifications 1632 and 1705 covering extension leads.

Special Advance* wire (60/40 copper-nickel) is for use with copper up to 400°C and with iron up to 900°C. The EMF requirements of these two combinations vary according to individual specifications. Special Advance* wires can be selected in most cases to meet these varying demands within the usual tolerances.

Matched Advance* Iron Wires The non-availability of a Standard Iron and the variation of EMF properties experienced with different iron supplies result in some difficulty in reproducing thermocouple EMF properties. To overcome this difficulty we are now able to provide a Special Iron wire matched with Special Advance* to meet certain standard EMF requirements within the normal tolerances.

If you are interested in thermocouple alloys, then you may like to have a copy of Data Sheet No. 2, for reference.

*REGD. TRADE MARK

BRITISH DRIVER-HARRIS CO LTD

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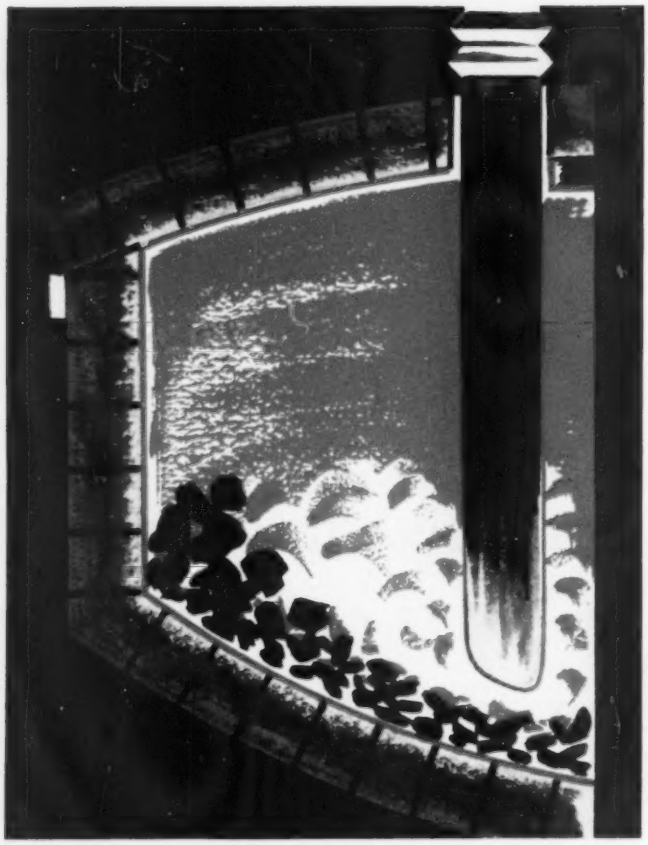

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"Acheson" Graphite Electrodes are manufactured from specially selected high grade raw materials which are carefully processed at all stages of manufacture under controlled conditions to give a final electrode for your arc furnaces with these properties at their optimum—

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EXCEPTIONAL THERMAL SHOCK RESISTANCE

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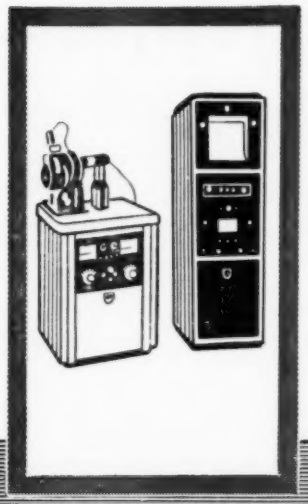

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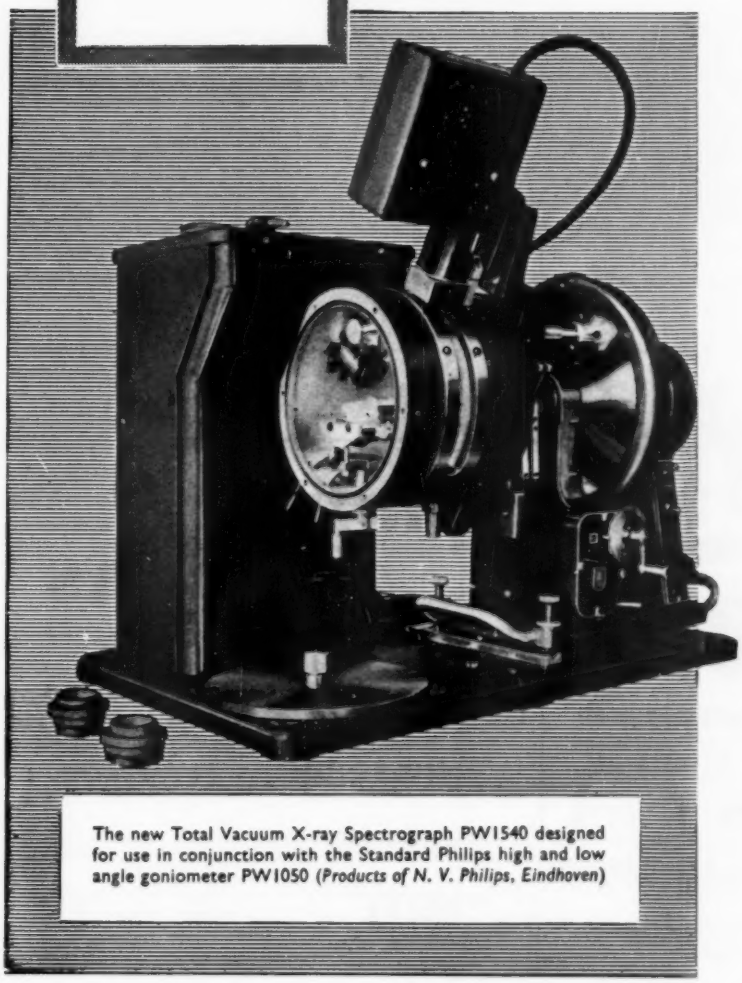
NOW—DOWN TO MAGNESIUM!



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PHILIPS new Total Vacuum Spectrographic Attachment PW1540 makes an outstanding scientific advance available to industry. The advantages of X-ray spectrography (non-destructive, rapid, qualitative and quantitative analysis) are now extended to all elements from uranium *down to MAGNESIUM.*

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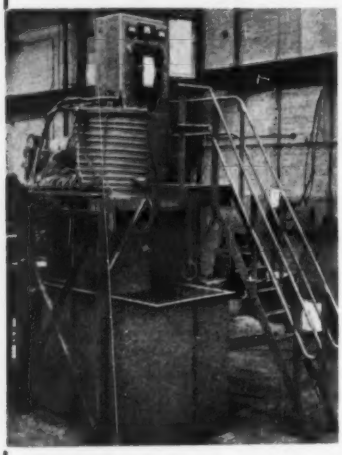
A New Vacuum Furnace—



has been developed, in which the charge can be heated AND QUENCHED without exposure to the atmosphere.

This equipment is invaluable for the heat-treatment of Molybdenum, Titanium, Tungsten, Stainless Steels, and all high-temperature alloys, including Nimonic.

The hot-zone is 24 in. in diameter, and 30 in. high. Molybdenum windings can raise the temperature to a maximum of 1,500° C. A recorder-controller accurately holds the temperature at any preset value.

A built-in sequence switch ensures easy, foolproof operation of the furnace, and enables the operator to carry out a heat-treatment cycle in the minimum length of time necessary.

The makers will be pleased to give further details, and to arrange an appointment for a demonstration of the equipment.

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SHELFORD CAMBRIDGE
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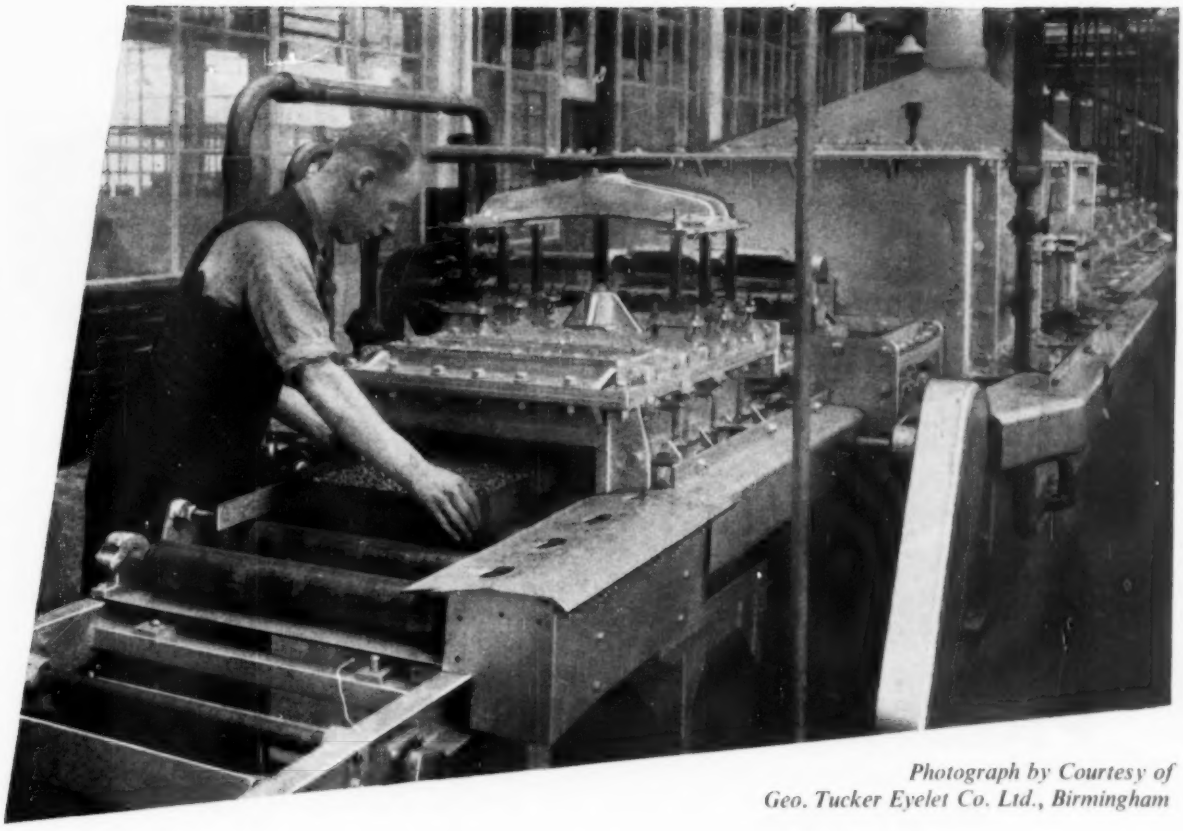

Photograph by Courtesy of
Geo. Tucker Eyelet Co. Ltd., Birmingham

one, two, buckle my shoe . . .

Of course, the buckles have changed to eyelets, but the rhyme holds good, for there are two INCANDESCENT roller hearth furnaces in this factory, bright annealing 8 cwt. of steel and brass eyelets an hour.

INCANDESCENT roller hearth furnaces use centrifugally cast nickel-chromium alloy rollers for temperatures up to 1,000°C., and sillimanite compression rollers for use at higher temperatures. Both are exclusive INCANDESCENT features. Heating is by gas-fired radiant tubes above and below the rollers giving a high rate of heat transfer and uniformity of heating. The protective atmosphere is supplied by INCANDESCENT exothermic gas generators.

INCANDESCENT

THE INCANDESCENT HEAT CO. LTD. SMETHWICK · ENGLAND

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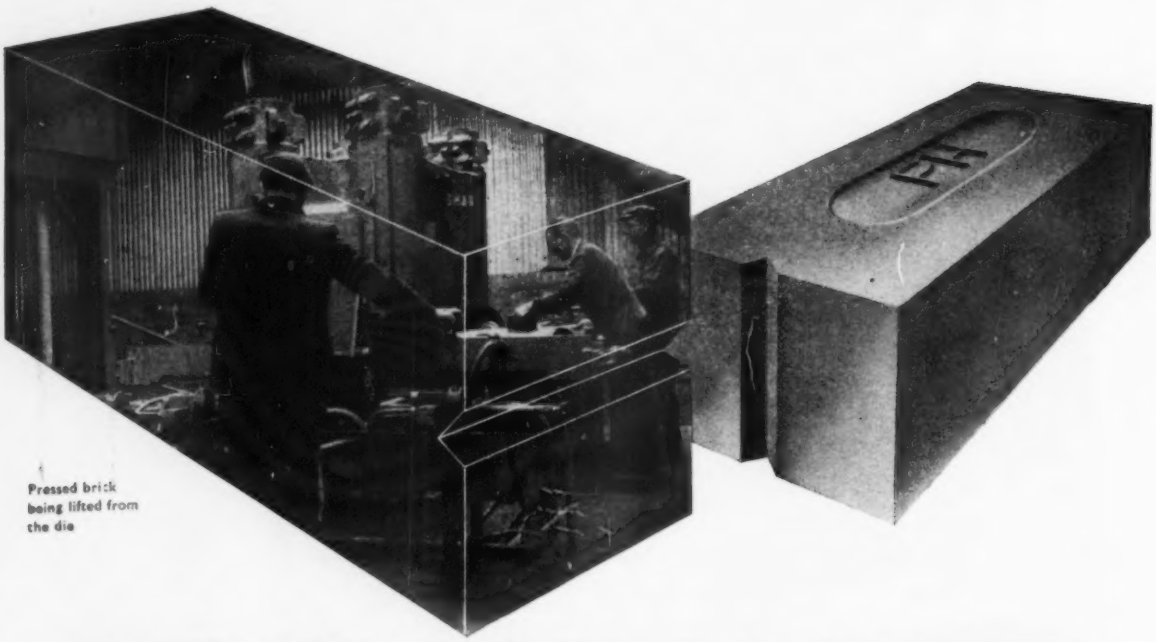


Pressed brick being lifted from the die

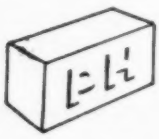
PRESSING PROBLEM SOLVED

Pickford Holland install the latest hydraulic presses for standard and special shapes

Refractory bricks today must be absolutely accurate in size and shape. These qualities, combined with unerring consistency in texture and performance are achieved by Pickford Holland through the medium of the most modern plant and equipment.

In Pickford Holland works, the very latest crushing, grinding and mixing plant, powerful hydraulic presses and continuous tunnel firing kilns have been and are being installed. Rigid control of the various processes is strictly observed, and the finished bricks are carefully inspected and tested before being despatched to the consumer.

More and more Pickford Holland refractory bricks are being supplied to steel and other industries throughout the world and the demand still grows. This surely points to the success of this policy of plant modernisation and is a tribute to the lasting service that these bricks give.



PICKFORD HOLLAND *Refractory Bricks*

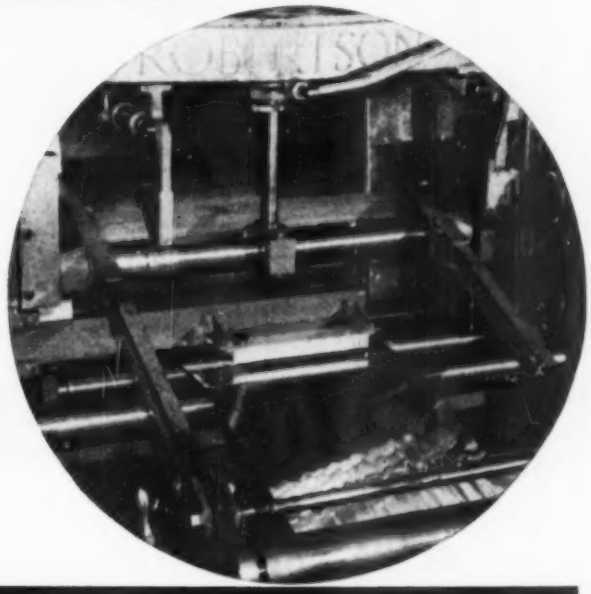
Consistent in Size, Shape, Texture and Performance

PICKFORD, HOLLAND & CO. LTD., 381 FULWOOD ROAD, SHEFFIELD 10. TELEPHONE 33921

Baldwin Atomat Nucleonic Thickness Gauges

ACCURATE, CONTINUOUS, NON-CONTACT INSPECTION

SAVES MATERIAL, LABOUR AND TIME!



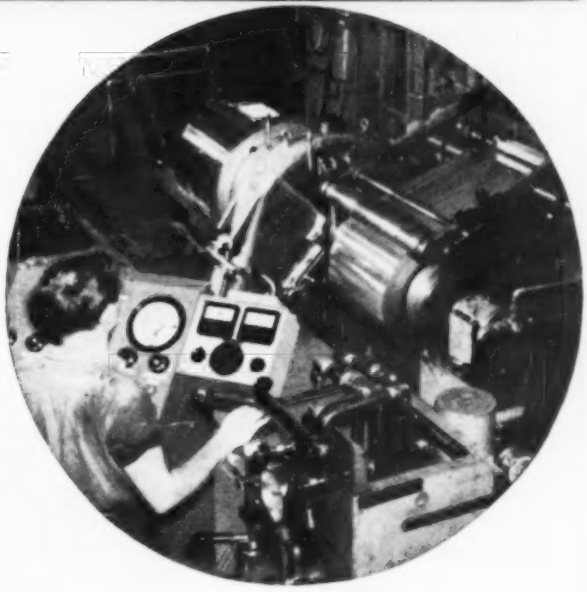
The Atomat Principle

RAY SOURCE
MATERIAL
RAY DETECTOR
Amount of rays passing through material indicates thickness or weight per unit area.

That's the very basic explanation of the Atomat principle. There are three main gauges; the Atomat Cold Strip Gauge, the Hot Strip Gauge and the Beta Gauge.
In addition there are special purpose variations, made to meet the requirements of many different industries.

HERE'S WHAT AN ATOMAT GAUGE CAN OFFER YOU

- **Time and material saving both in production and setting up**
- **High accuracy**
- **Calibration in your usual units of measurement**
- **Continuous readings for materials in constant production**
- **Auto standardisation and control if you require**
- **Minimum maintenance**



Baldwin Atomats are already boosting production and cutting costs in the paper, metal rolling, rubber and plastics industries. Highly successful applications also include the measuring of selenium on aluminium, coatings of paint and lacquers, density of wood chips, coatings of grit on abrasive papers and padding and resin impregnation in the textile industry. But the potential of Baldwin Atomat Nucleonic Gauges has hardly been tapped.
Is there a place for them in your plant?

INSTRUMENT DIVISION

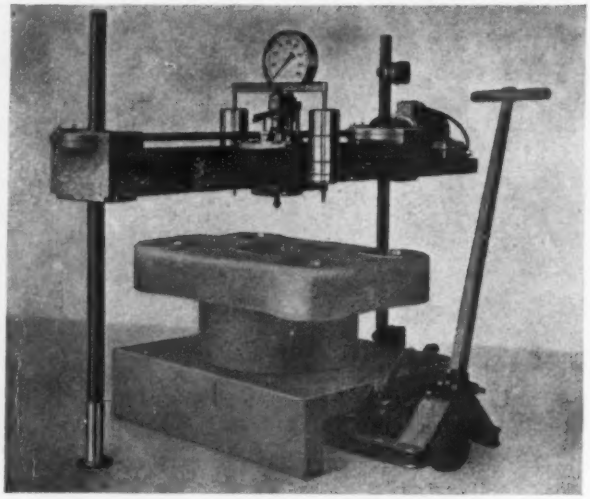
Send for the Baldwin Brochure MA/124. It gives full information on Atomat Gauges clearly and concisely.

BALDWIN INDUSTRIAL CONTROLS

Baldwin Instrument Company Limited, Dartford, Kent A Harper Group Company

DARTFORD 6411 & 2948 *Cables and Telex: Baldwin, Dartford*

JACKMAN FOR HARDNESS TESTING EQUIPMENT



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WE SHOW A BEAM TYPE BRINELL MOTORISED FOR VERTICAL MOVEMENT.

TEST HEAD CAN BE SLID ALONG BEAM BY HAND.

WIDTH BETWEEN COLUMNS 52″
HEIGHT UNDER TEST BALL 6″ TO 60″

STANDARD BENCH TYPE AND OTHER SPECIAL MACHINES AVAILABLE.

PLEASE WRITE FOR BULLETIN No. 2

ALPHA CARBOMETER

FOR RAPID AND ACCURATE DETERMINATION OF CARBON IN STEEL BATHS.

TOTAL TIME OF MAKING TEST 1½-2½ MINUTES INCLUDING PREPARATION OF SPECIMEN. ACCURACY IS ±0·01%

SIMPLE TO OPERATE.

PROVIDES COMPLETE CONTROL OF STEEL BATH.

USED IN THE LEADING STEEL WORKS OF THE WORLD.

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VULCAN WORKS : BLACKFRIARS ROAD : MANCHESTER, 3.

Telephone: DEAnsgate 4648 (3 lines) *Telegrams: BLAST, MANCHESTER*

When temperatures run high...

"It's the devil's own job finding a brick that will both stand up to high temperatures, and resist...."

"What do you call high temperatures?"

"Over 1600° Centigrade.... to stand that and resist—**really** resist—slag attack.
And do both of these for a long time without cracking."

"Quite a proposition."

"More than a proposition. It's a necessity. Also it has to be a brick suitable for a multitude of applications."

"Such as?"

"Well, it's not only the Steel Industry; there are the glass producers and high temperature kiln people too. It's wanted for soaking pits, reheating furnaces, and burner blocks—wherever operating conditions are really severe."

"I think I know the rest. Apart from the resistance to slag attack you mentioned it must have low spalling tendency and very high mechanical strength. In fact, a super duty brick. Right?"

"I believe you know something. What's the brick?"

"The Consett '735' High Grade Alumina Brick—ideal for the super duty and the multitude of applications you mentioned."

"Didn't know you were a refractories expert."

"I'm not—the experts are at Consett Iron Company Limited—they've got a whole range of refractories.... CONSETT 341—that's their number."

"Thanks—I'll ring them at once."

CONSETT REFRACTORIES

CONSETT REFRACTORIES

CONSETT IRON COMPANY LIMITED,
CONSETT, COUNTY DURHAM.
Telephone: CONSETT 341

WORLD'S MOST POWERFUL COBALT 60 RADIOGRAPHIC UNIT

NEWTON VICTOR COBALT 60 INDUSTRIAL EQUIPMENT

being set up for radiographic inspection of 4 in. welded plates which will later be shipped to Latina, Italy, for the new reactor vessel under construction by Whessoe Limited, Darlington, England.

This high intensity cobalt container for non-destructive testing is almost certainly the world's most powerful industrial radiographic unit. It embodies the results of years of experience in related medical equipment of Newton Victor manufacture.

Safe operation, ease of adjustment and robust construction are all provided by a unit which incorporates a source of 2,000 curies for the radiographic examination of welded seams in steel plate up to 6 in thick. Needing only small electric currents for control, and independent of water supplies it is suitable for work on open constructional sites in remote areas.

Check these important points:

POWERFUL The unit provides the equivalent of 3 million volt x-ray testing for 3 in to 6 in steel, with comparable sensitivity and economical exposure times.

SAFE Fully loaded provides ample protection—0.3 milli-roentgens per hour at 1 metre. Source housed in lead and tungsten alloy protective container is easily and safely moved from 'protected' to exposure position by use of the compact control unit.

ACCURATE Beam of radiation 6 in or 12 in wide by 5 ft long (15 or 30 cm by 150 cm) at a distance of 12 ft (360 cm) from source. Special light projector guide beam accurately 'pinpoints' centre of radioactive beam on specimen.

EASILY ADJUSTED Angulating mechanism permits rotation through 350° about both horizontal and vertical axes.

RELIABLE Stout construction and dust-tight, moisture-proof enclosure of container gives reliable operation under adverse conditions and extremes of climate.

SEND THIS COUPON for further details

To: Newton Victor Ltd., x-ray department of Metropolitan-Vickers Electrical Company Limited, 132, Long Acre, London, W.C.2, England.

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X-Ray Department of

METROPOLITAN-VICKERS

ELECTRICAL CO. LTD. · TRAFFORD PARK · MANCHESTER 17

An A.E.I. Company

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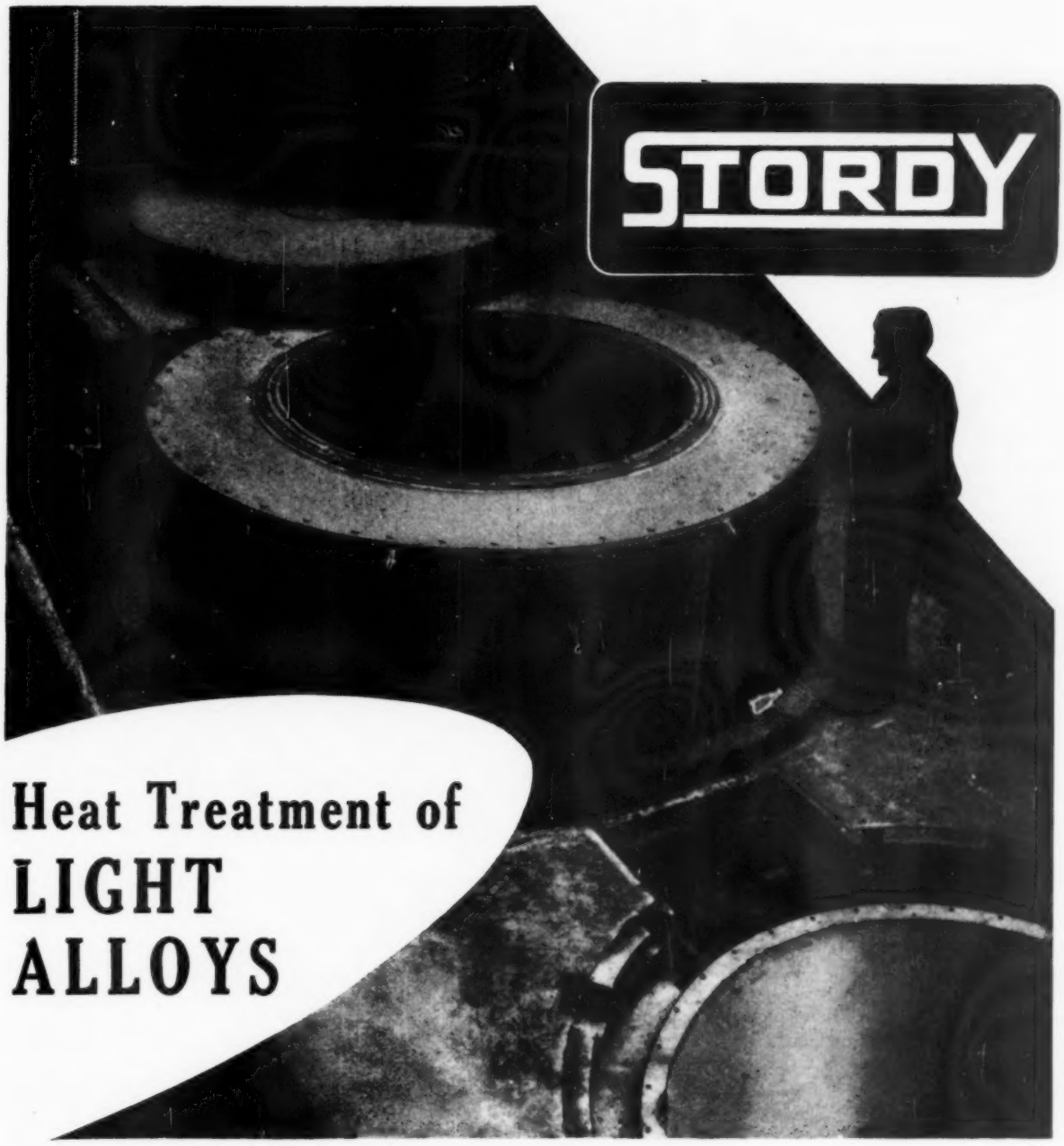


Heat Treatment of LIGHT ALLOYS

Greater efficiency, more precise control, higher output with considerably less maintenance and running costs—these are the features that place these STORDY Electric Furnaces ahead for light alloy treatment. Unit construction of heater battery allows ready derating adjustment for precipitation treatment and annealing—with same precise temperature control. In addition, the heater battery is remote from the furnace chamber and therefore easily accessible for inspection without dismantling. The large capacity centrifugal fan gives greater air circulation.

The furnace illustrated is for the heat treatment of extruded sections—work dimensions 5 ft. diameter by 8 ft. deep.

STORDY ENGINEERING LIMITED

CUMBRIA HOUSE · GOLDTHORN HILL · WOLVERHAMPTON

SM/SE 1807

The Vespa Story

"Out of darkness cometh light"

Post-war Italy was bankrupt—physically, politically and economically it was a scene of desolation. Yet it was in this unprepossessing economic environment that Dr. Piaggio in Genoa started an enterprise which has revolutionised post-war personal travel throughout the world. Within twelve months of Mussolini's mutilation, he had produced over two thousand of the now world-famous Vespa Motor Scooters. Within ten years he was to make a million. Now, the Italian Vespa Company employs more than 4,000 workpeople and the robust little Vespa has completely democratised personal transport. Workmen in factories, doctors on their rounds, bankers, stockbrokers and film stars in every country are all proud Vespa owners. In fact, the Vespa has eradicated motor car snobbery and made tens of thousands of womenfolk motorists for the first time.

At home, pre-war, the name of Douglas was famous in the motor cycle world, but in the immediate post-war years this famous Douglas Company at Bristol had fallen on evil times. It was in the hands of the receiver when Claude McCormack, a Coventry Motor Engineer, took over what seemed an insuperable task of rehabilitation. By chance, whilst holidaying in Italy, he saw the Vespa, and although in charge of a bankrupt firm he nevertheless persuaded the then well-established Italian Vespa Company to grant manufacturing rights to Douglas. The Vespa brought success to the bankrupt Douglas organisation; the jobs of more than a thousand people were saved; bank overdrafts were repaid; shareholders realised unhoped-for prices for shares worth previously only a few coppers, and the Douglas Company became worthy of purchase by the powerful Westinghouse Brake and Signal Company Ltd. Thus the birth of the British Vespa took place also in an environment of economic desolation. Now the Douglas Company at Bristol employs nearly 2,000 people and the output of Douglas Vespas has topped the 100,000 mark. Quite recently the 'Financial Times' reported that the domination of the United Kingdom scooter market by imported European models looks like ending. United Kingdom production has increased 100% in the past twelve months and imports only a quarter, whilst British exports to the United States, the Commonwealth and Scandinavia are expanding. If any proof is required that trials and tribulations inspire mankind to prodigious effort, surely the Vespa story is a pertinent example.

At Kingswood there is a modern Vespa production line modelled on the motor car industry. Large presses stamp out the framework and overhead conveyors take the chassis and components to the paint and assembly shops.

However, the Vespa's attractive colour coat serves as a protective mantle to the robust and reliable power, transmission and braking systems which lie beneath. The construction of the components for these systems presents many problems for the metallurgist. Most of them depend upon heat treatment, carburising, tempering, etc., which demand very close time/temperature

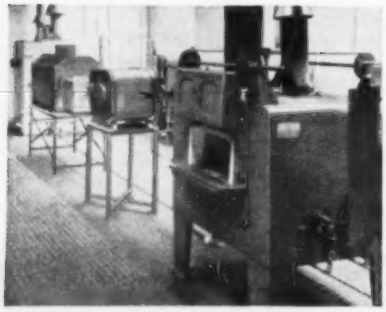


Fig. 2. A view of the new industrial gas showroom opened by the South Western Gas Board.

schedules. For this reason most of the furnaces are on automatic temperature control where thermocouples measure the temperature and transmit an electrical signal to control pyrometers which operate valves in the gas supply according to the measured temperature. This ensures that the temperature never varies from the close limits necessary for correct heat treatment which largely determines the life of the components. The Douglas Company uses town gas supplied by the South Western Gas Board for melting, hardening, tempering and carburising as well as stoving the synthetic paint finishes. For these purposes town gas is the most suitable fuel because its declared calorific value lends it well to precise automatic control. Other advantages are, of course, that there are no interruptions for fuel deliveries, and the gas meter provides the simplest and cheapest form of fluid fuel costing.

In the foundry gas is used for core drying, and aluminium alloy melting is carried out in three gas-fired melting furnaces, the molten metal being used for the gravity die-casting of the light alloy components. Crankshafts, gears, etc. require special heat treatment to fit them for their arduous life, and in the Carburising Shop there are three gas-fired muffle furnaces as well as a high-speed tempering furnace. Other non-ferrous components are treated in gas-fired salt bath furnaces.

The standard of finish on the Douglas Vespa is extremely high. The chassis, mudguards, etc. having been assembled, stress-relieved and filled, pass on conveyors into the finishing shop. After being sprayed with a number of priming and finishing coats of paint the components pass, still on conveyors, into a gas-fired infra-red paint stoving oven which was specially designed to suit the awkward shape of the chassis, thereby ensuring that each part of the painted surface received adequate heat. Again town gas was chosen as the fuel because it lends itself more easily to the close time/temperature schedules required to cure the modern synthetic paints.

Undoubtedly the large output of Vespa Scooters has benefited from the close co-operation between the South Western Gas Board, the equipment suppliers and the Douglas Company. As part of its service to industrialists in the South West the South Western Gas Board has recently opened an Industrial Gas Showroom where factory executives can inspect working examples of infra-red tunnels, natural draught oven furnaces, muffle furnaces, recirculating ovens, etc. Anyone can bring along the components in which they are interested and try them out with the equipment in advance of purchase. A small pottery kiln is in great demand by schools in the district, and examples of decorated and glazed pottery reflect high credit not only upon the schoolboys and girls but upon the precise time/temperature schedules obtainable with town gas in a relatively inexpensive kiln. In addition, there is a wide range of gas burners together with ancillary equipment such as flame protection and ignition systems where automatic temperature control figures prominently.

This Industrial Gas Showroom is one positive example whereby the Gas Industry through its Industrial Gas Officers at the Area Gas Boards is serving industry—these officers from all over the United Kingdom meet regularly to discuss developments, so that any manufacturer approaching any Area Gas Board has at his disposal the pooled knowledge throughout the country in some 4,000 different trades and industries served by gas. One practical result of this service is reflected in the Douglas plant at Kingswood, Bristol —and the name of Douglas is in turn reflected in the ever-increasing market for its ever popular and glamorous Vespa Scooter.

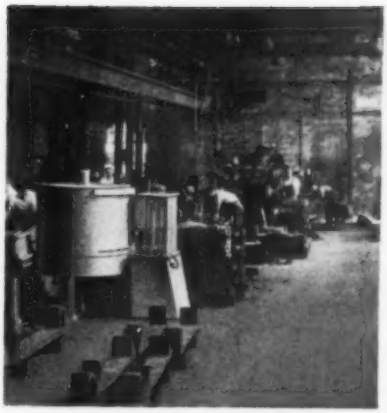


Fig. 4. A view of the gas-heated core drying installation in the foundry of Douglas Engineering (Kingswood) Ltd.

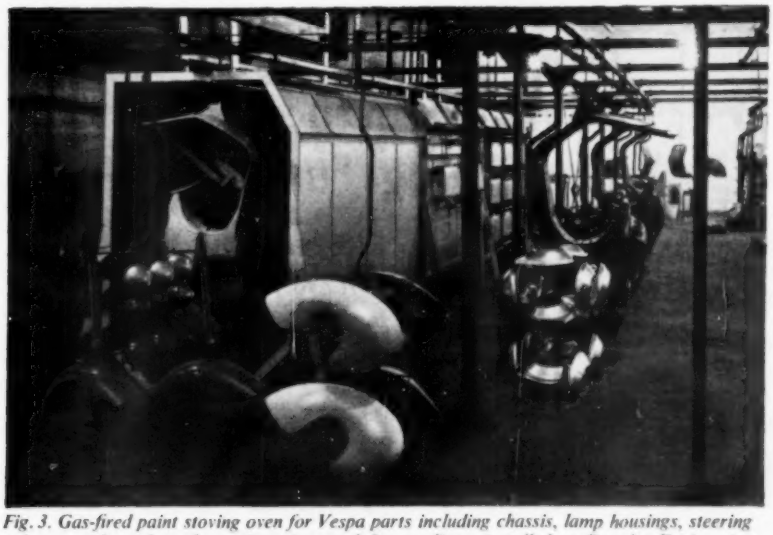
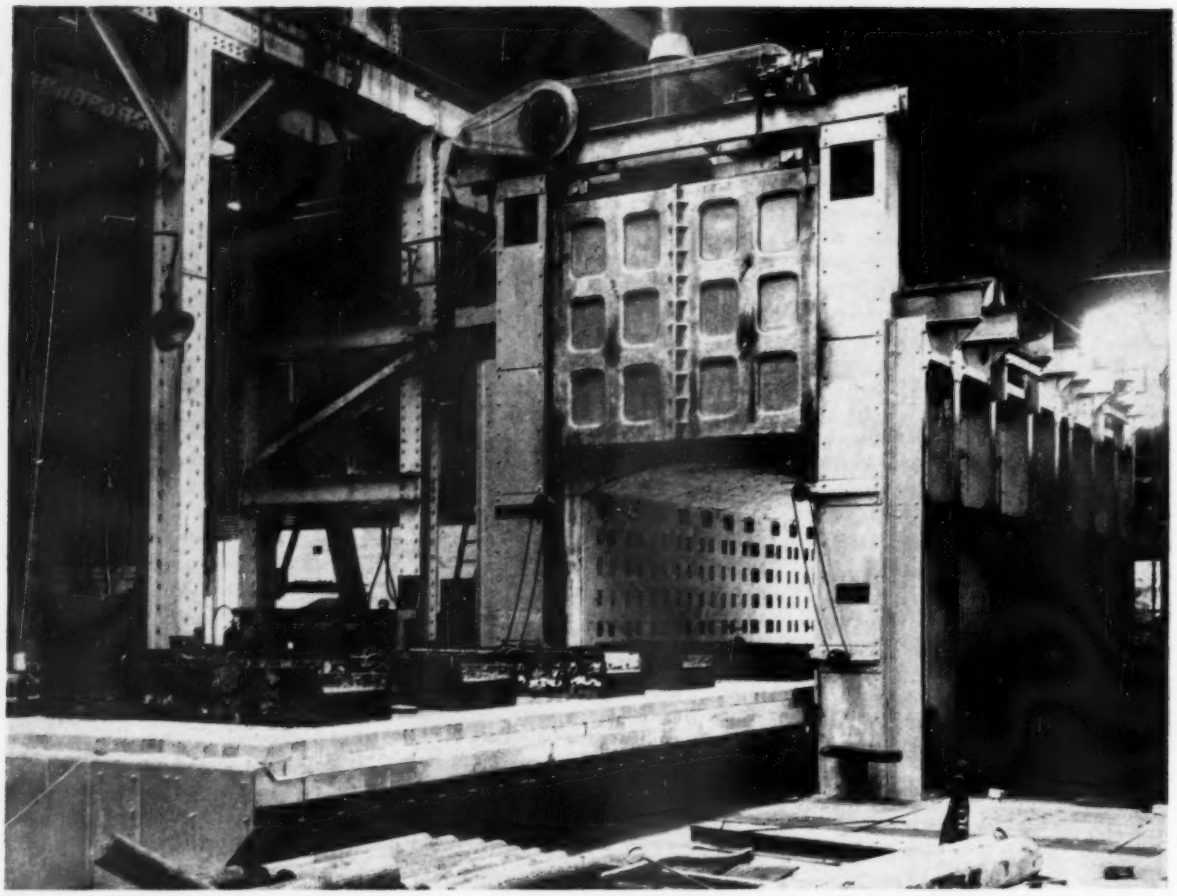


Fig. 3. Gas-fired paint stoving oven for Vespa parts including chassis, lamp housings, steering columns with mudguards, engine wings and fan cowlings, installed at Douglas Engineering (Kingswood) Ltd.

Scottish Gas Board, Edinburgh.
Northern Gas Board, Newcastle-upon-Tyne.
North Western Gas Board, Manchester.
North Eastern Gas Board, Leeds.
East Midlands Gas Board, Leicester.
West Midlands Gas Board, Birmingham.
Wales Gas Board, Cardiff.
Eastern Gas Board, Watford.
North Thames Gas Board, London, W.8.
South Eastern Gas Board, Croydon.
Southern Gas Board, Southampton.
South Western Gas Board, Bath.

The Gas Council, 1 Grosvenor Place, London, S.W.1.



Photograph by courtesy of Messrs. Thos. Firth & John Brown Ltd., Sheffield.

Brayshaw

Town's Gas Fired Bogie Hearth Tempering Furnace

of the products recirculation type installed at Messrs. Thos. Firth & John Brown Ltd., Sheffield.

the above illustration is one of the many installations supplied to leading manufacturers Brayshaw Industrial Furnaces for all purposes including:

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having supplied more Blast Furnace Linings than any other Manufacturer.*

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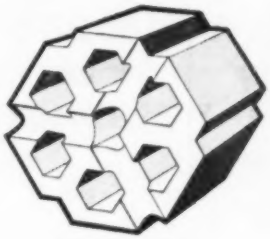

* Carblox Limited now offer the TEMCO pattern chequer brick manufactured by our parent company, Thomas Marshall & Co. (Loxley) Ltd. This new brick has an effective brick mass of 99 per cent.—much higher than any other type of chequer. Details sent on request.

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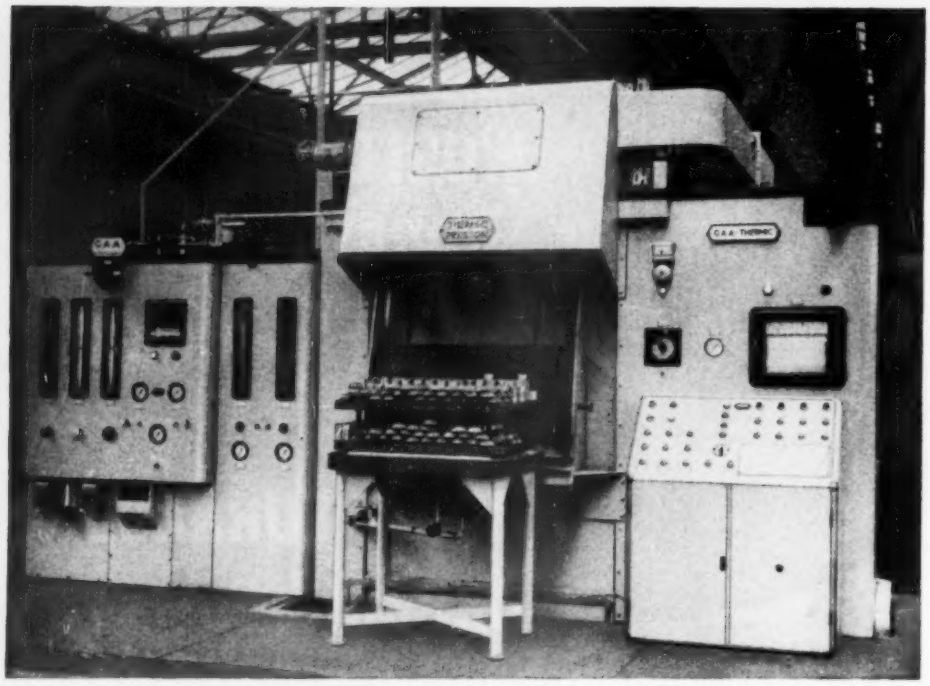

GAS fired furnace of new design for **GAS** carburising and clean heat treatment in controlled atmospheres is now a working exhibit at the Board's Heat Treatment Service establishment.

Come and see it at work or send your own components to be treated. Orders can be accepted for all types of commercial heat treatment.

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HEAT TREATMENT SERVICE

WEST MIDLANDS GAS BOARD,

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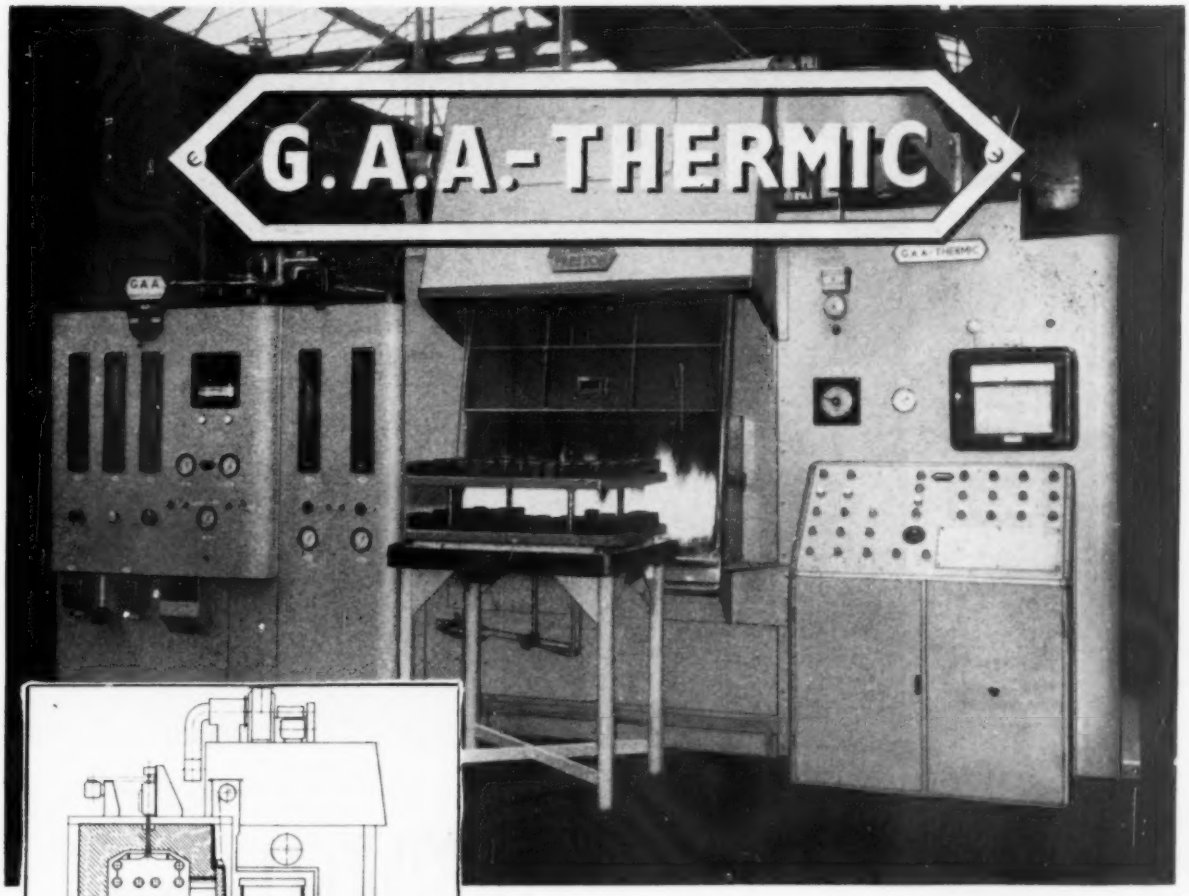

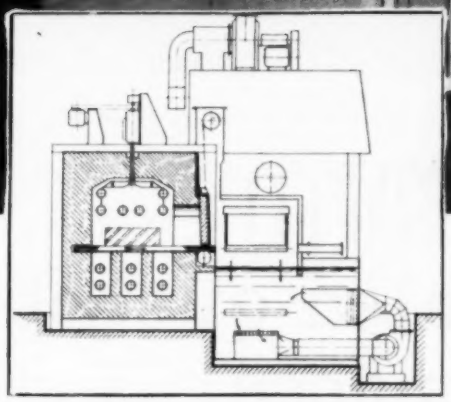

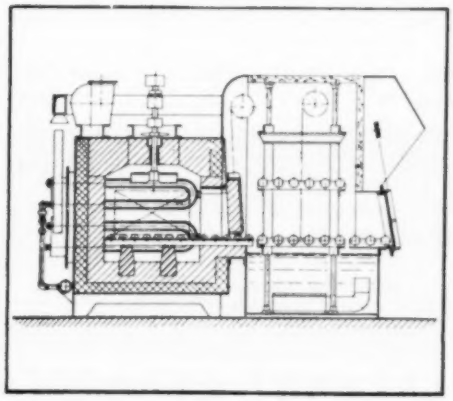

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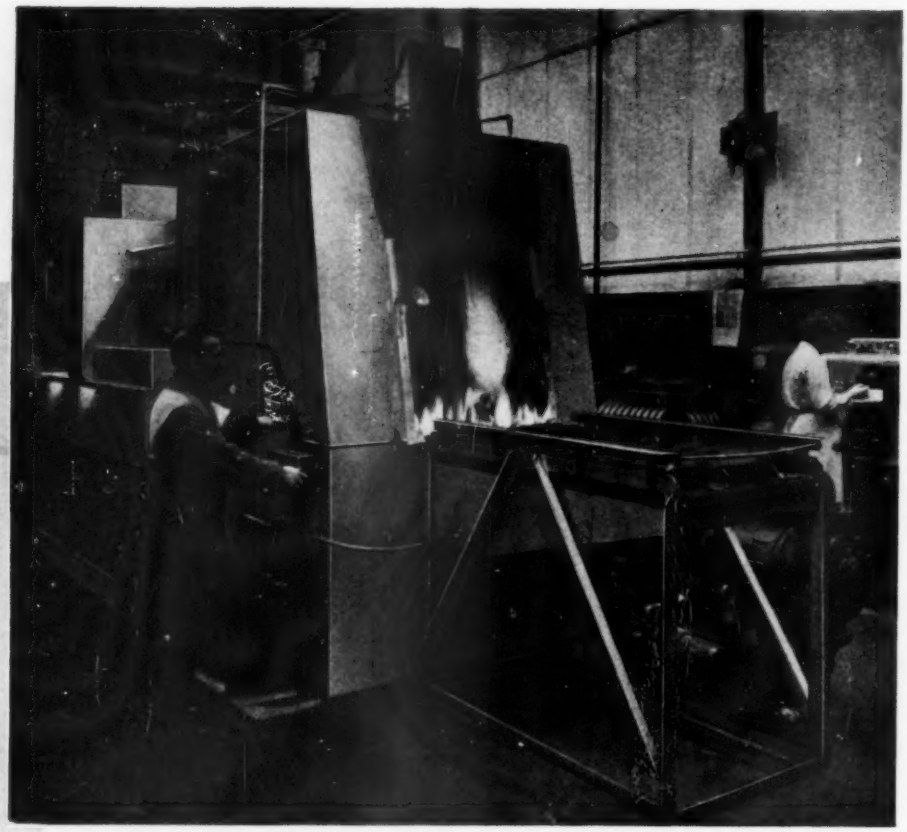
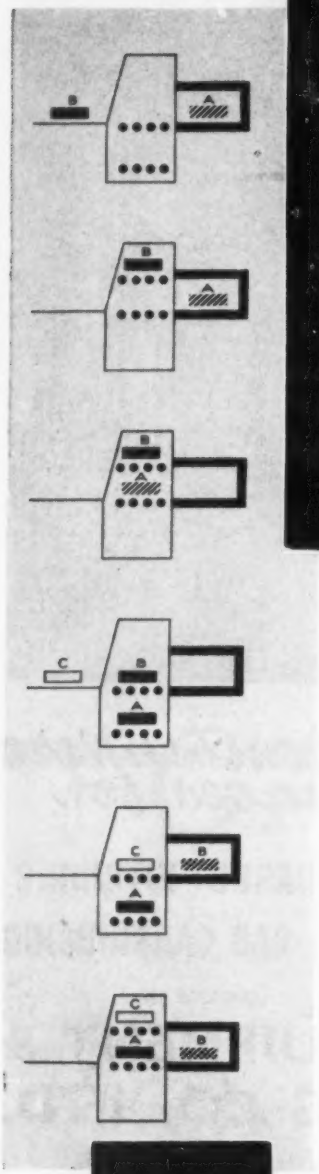


Completely mechanised, straight-through "ACE" furnace by Wild-Barfield. (Courtesy G. W. King Ltd., Stevenage, Herts.)



WILD BARFIELD 'ACE' sealed quench furnaces

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- CENTRAL CONTROL CUBICLE. All doors and quench lift hydraulically operated
- RANGE OF SIZES. Covers all normal requirements

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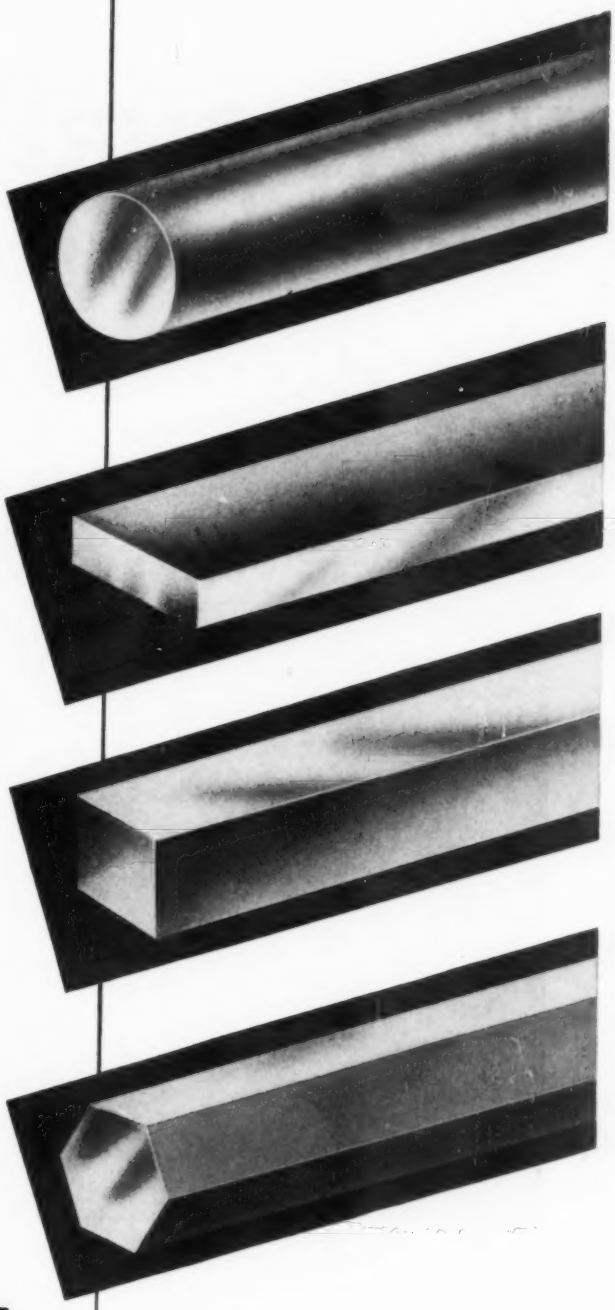

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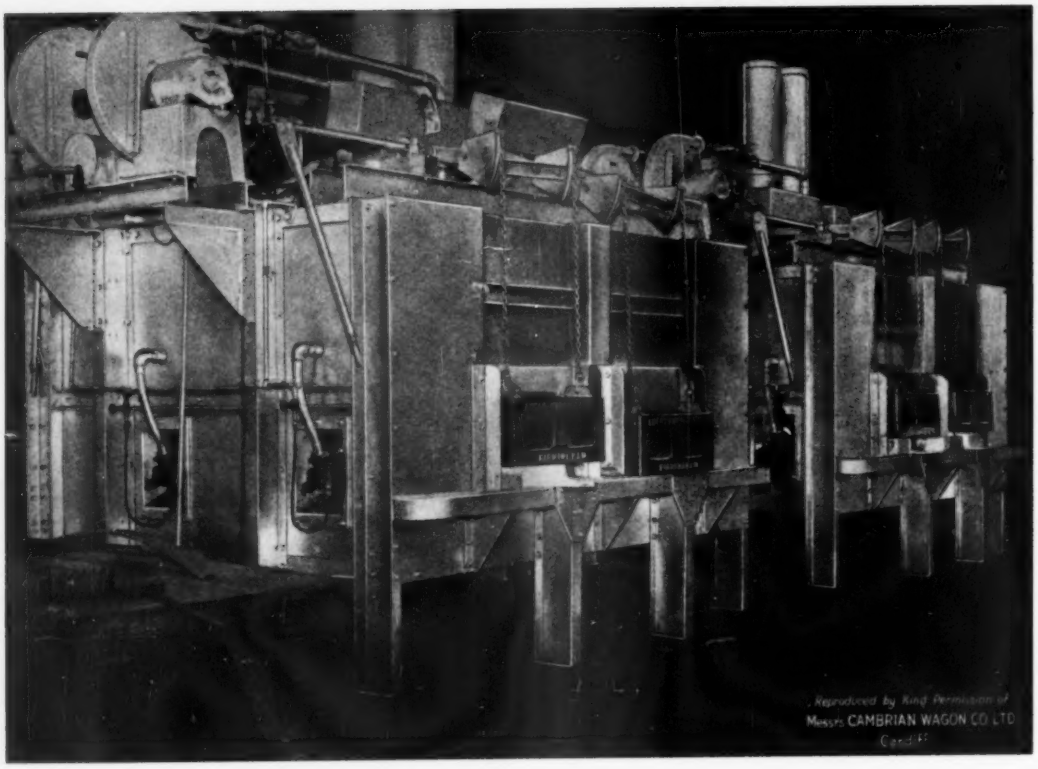

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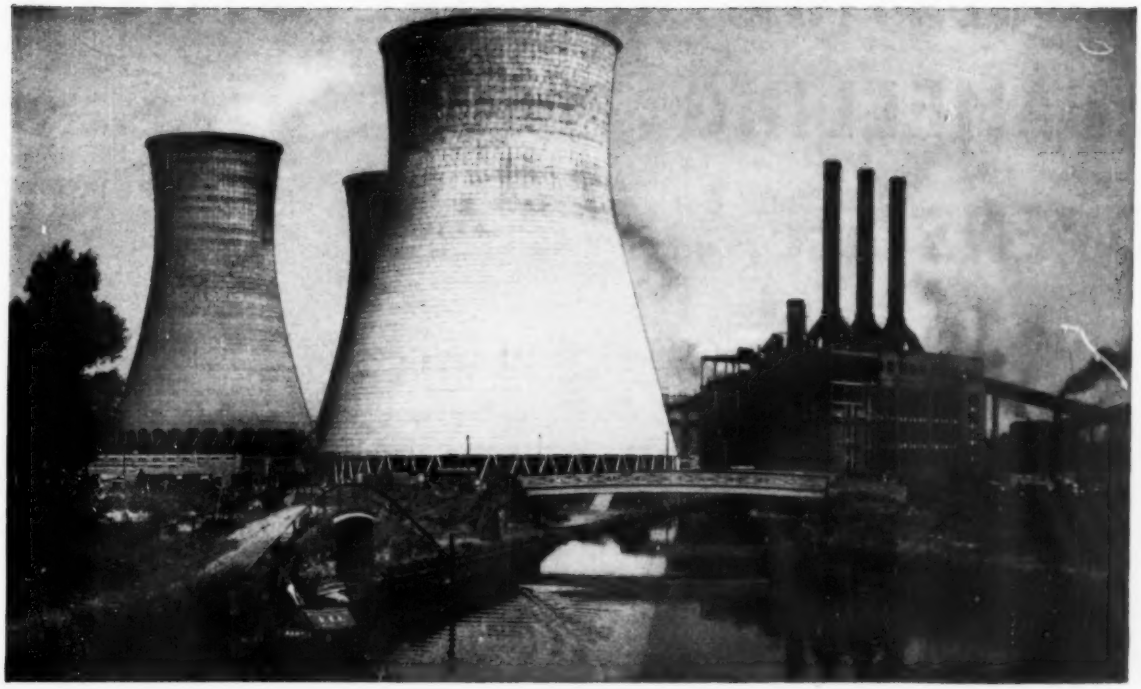
AND
FURNACE CONVERSIONS



Staffordshire Landscapes

The perfect marriage of old and new takes place as the traditional canal boat brings fuel to today's power generators.

Change is not always ruthless, nor synonymous with replacement in South Staffordshire, where, when benefits accrue, the new teams happily with the old, taking the best of modern methods and ancient skills and blending them into a realistic approach to the problems of an atom age.

Progress in Staffordshire, bringing almost every major improvement in the technique of iron-founding since 1700, is apparent in the landscape of the County as well as in its products.

For almost a century and a half Pig Iron has been manufactured at Darlaston Iron Works. Today, the most modern methods of metallurgical control of raw materials and the finished product, enables them to supply Pig Iron of consistent uniformity to the most exacting specification.

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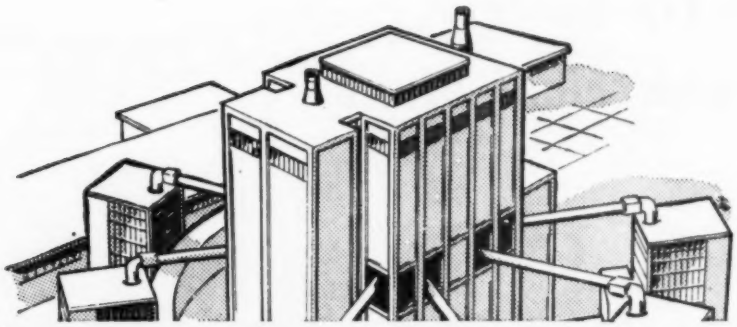

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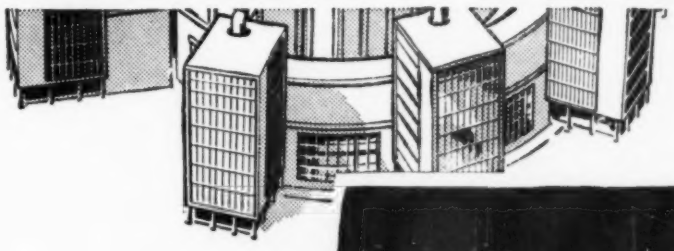
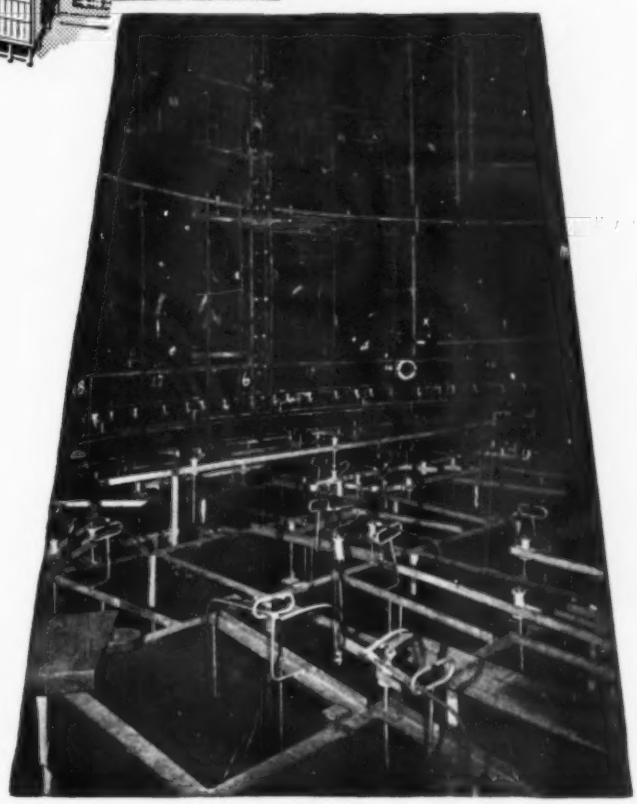


Reactor pressure vessel stress relieving installation planned, erected and supervised by EFCO



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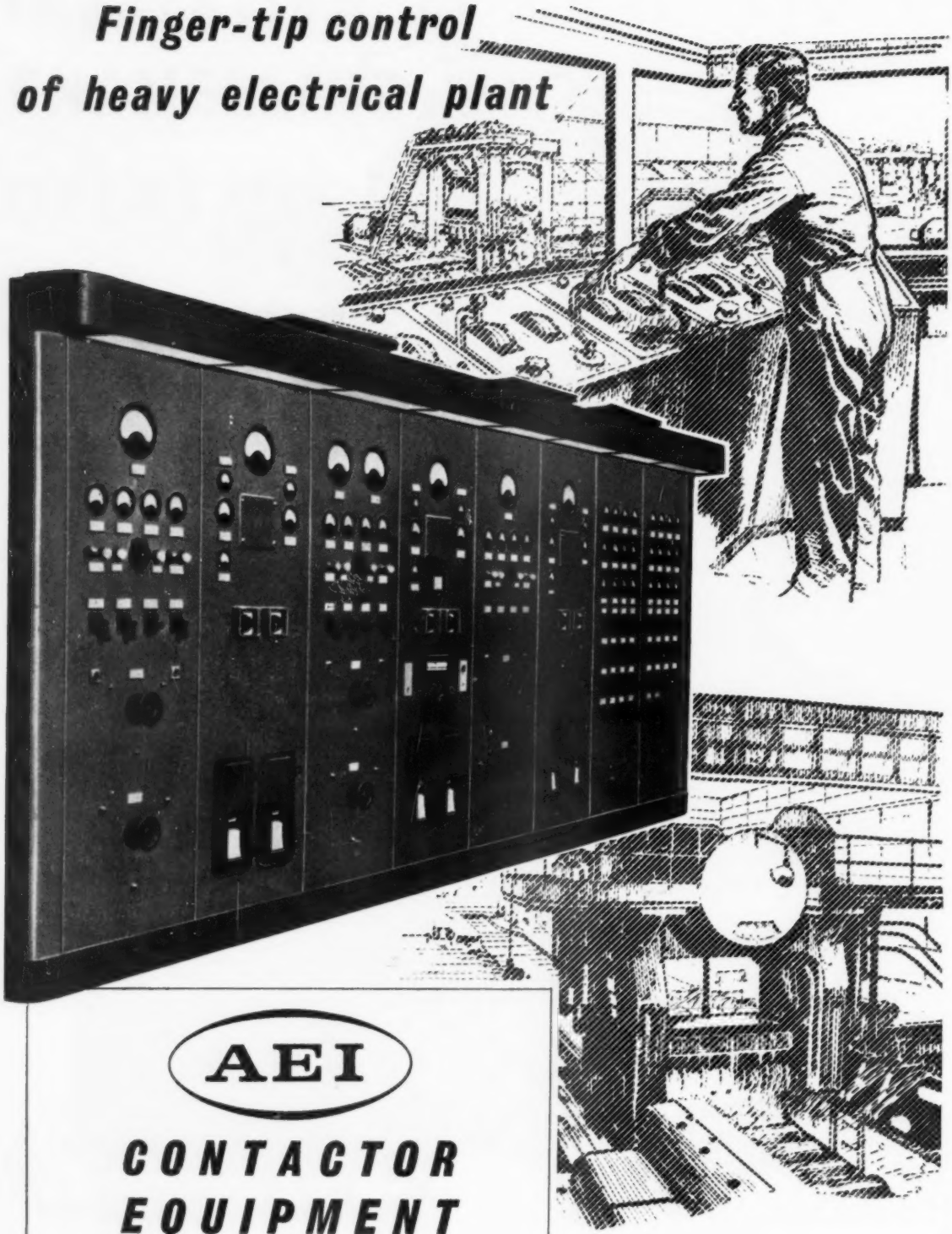

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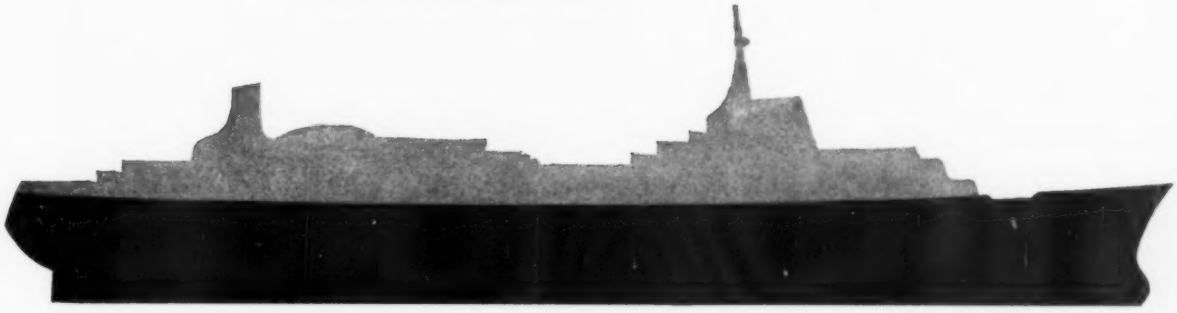

1000 TONS OF ALUMINIUM in the superstructure of "CANBERRA" enable two or three hundred more passengers to be carried in this new 45,000 ton P & O ship. The owners and builders have chosen aluminium for this, the largest passenger liner bound through the Suez Canal, not only to enable them to carry more passengers per voyage, but also to cut six days off the time to Australia. British Aluminium have already supplied almost 800 tons of aluminium alloy plates and extruded sections to Harland & Wolff Ltd, the builders.

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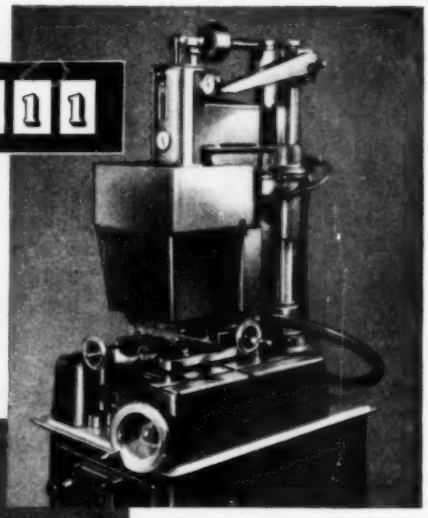

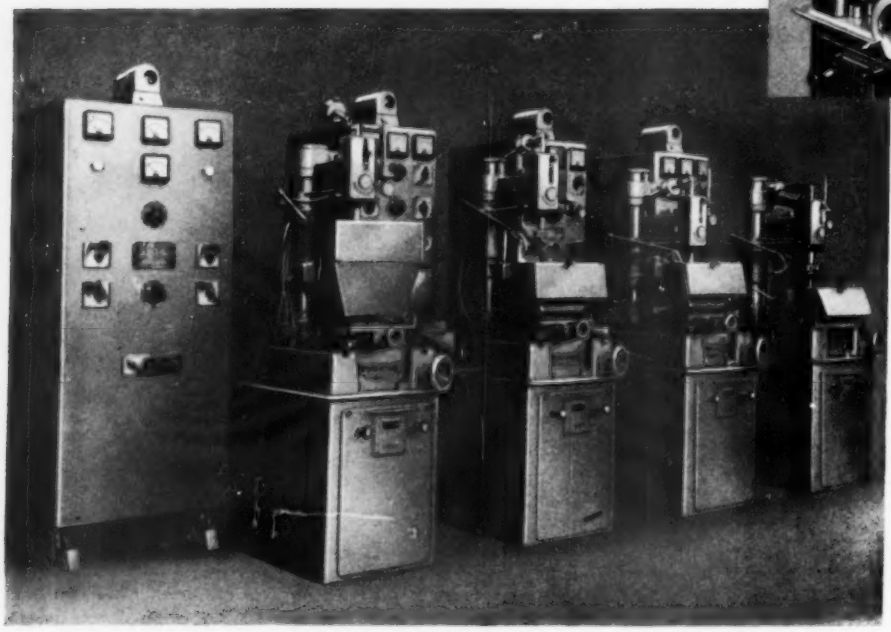

Up to four spark-heads can be operated from one control cabinet. The current is automatically cut off when the electrode has penetrated the workpiece to a predetermined depth allowing one operator to supervise a number of heads.

CAPABLE of operating three to eight times as fast as the Mark II model, depending on the type of material and finish required, the latest SPARCATRON spark erosion machine, Mark III, has exceptional accuracy and increased capacity. The new design also features ease of access for loading the table and setting the servo-head and the facility for quick and accurate alignment of the electrode. SPARCATRON affords the best means of "cutting" intricate shapes, profiles, forms, or impressions in both hard and soft current-conducting materials.

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Pioneered and established in the toolmaking industry for spark-machining and reconditioning press tools and dies and wire drawing and extrusion dies in cemented carbides and hardened steels. There are extensive applications for "cutting", reconditioning or altering flat and tangential form tools and similar components.

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Wild-Barfield Progressive Hardening Machine at MORRIS Engines Limited

Hardening of valve rocker shafts at Morris Engines Ltd., is carried out on Wild-Barfield Progressive Hardening Machines. (Note the hardness pattern on the rocker arm that is being removed.) This is a typical application of this proved unit of the well-known Wild-Barfield range of induction heating equipment.

Some technical facts.

This fixture caters for lengths from 1" to 30", or longer in special cases, diameters from ¼" upwards depending on the size of Wild-Barfield A.H.F. Generator used. A simple cam change enables any desired hardness pattern to be obtained giving hard and soft zones as required. The construction follows machine tool practice and incorporates traverse speed control which, together with power control on the generator, makes the equipment extremely versatile.

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INDUCTION HEATING SPEEDS PRODUCTION

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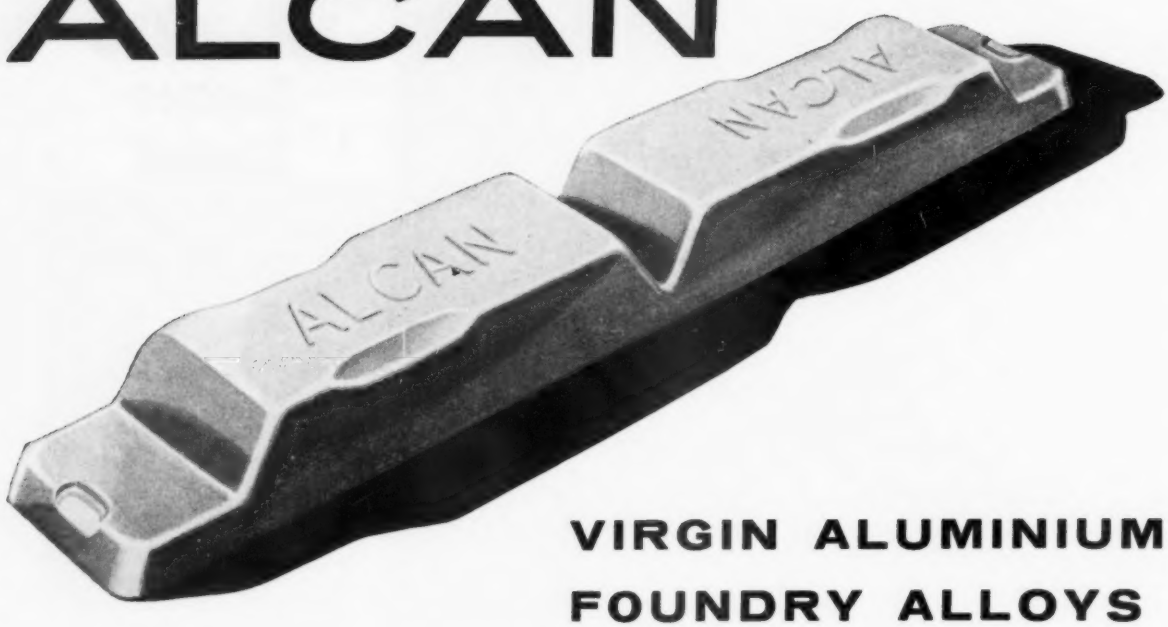

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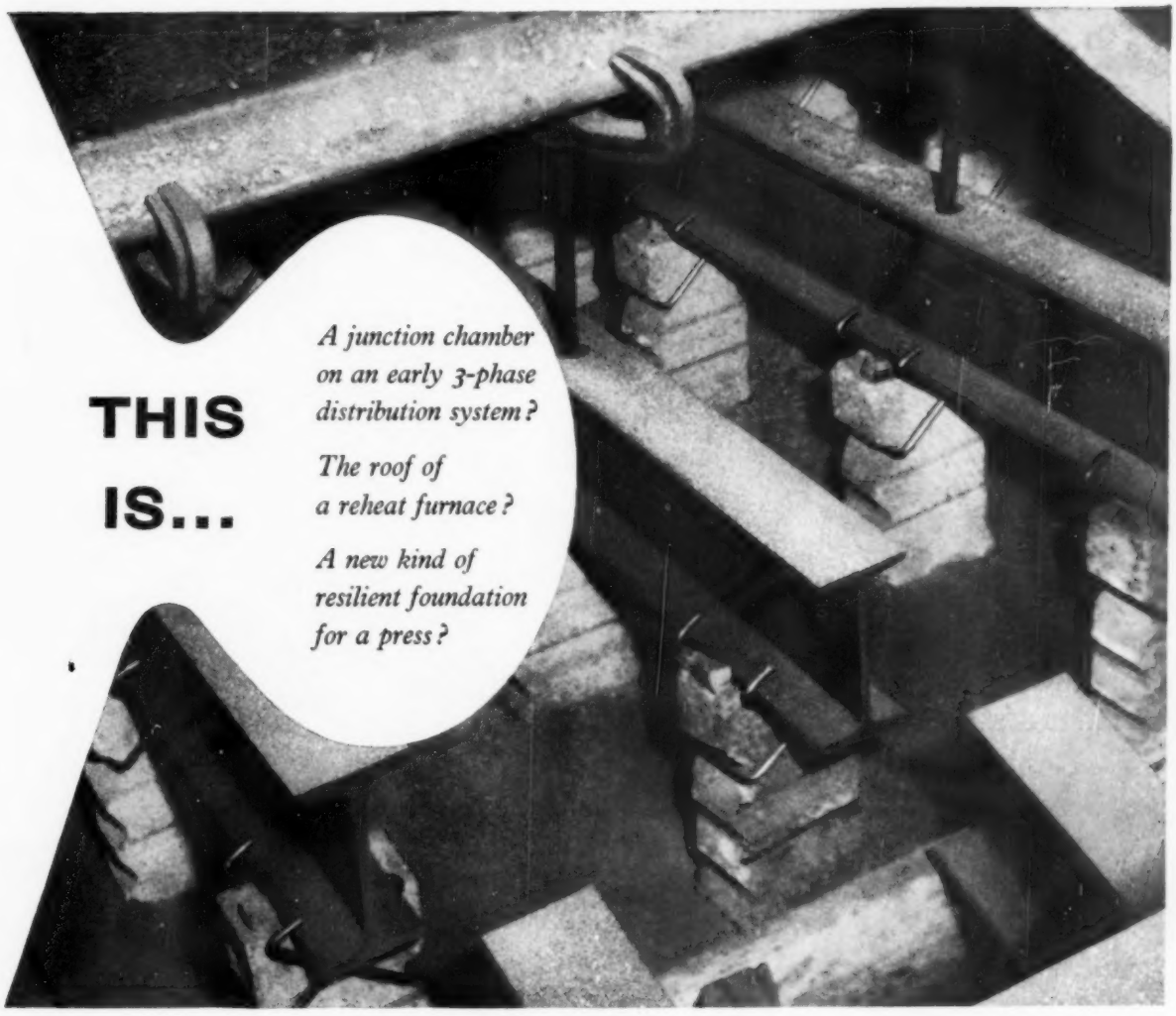
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The roof of a reheat furnace?
A new kind of resilient foundation for a press?

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The special anchor bricks hanging from the R.S.J's are secured by heat-resisting clips and will provide support through the full thickness of the refractory lining.

This roof was cast in "TRI-MOR" High Temperature Castable. It is a good example of the type of furnace lining which "TRI-MOR" refractories and Morgan's whole-hearted belief in monolithic structures have made possible.

Some of the most useful of the "TRI-MOR" refractories are:—

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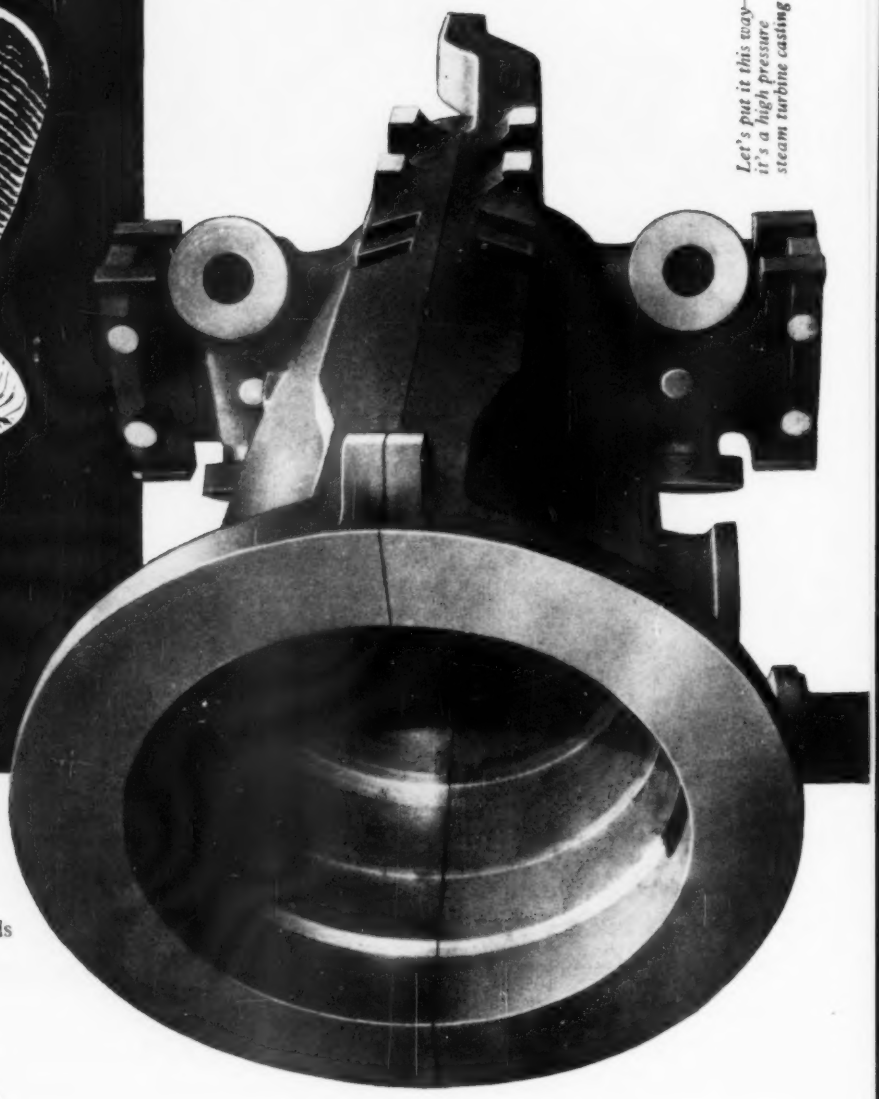

Let's put it this way—it's a high pressure steam turbine casing

There is no witchcraft, really, about the unvarying high quality of David Brown castings — though there are many other kinds of craft involved in their production. At the Penistone Foundries, the crafts of the steel maker, pattern maker and moulder are brought together and, with other skills, are co-ordinated into a complex production unit of supreme efficiency. Backed by unique metallurgical resources and using the most up-to-date plant and techniques, this organisation offers a completely reliable service for all types of steel casting.

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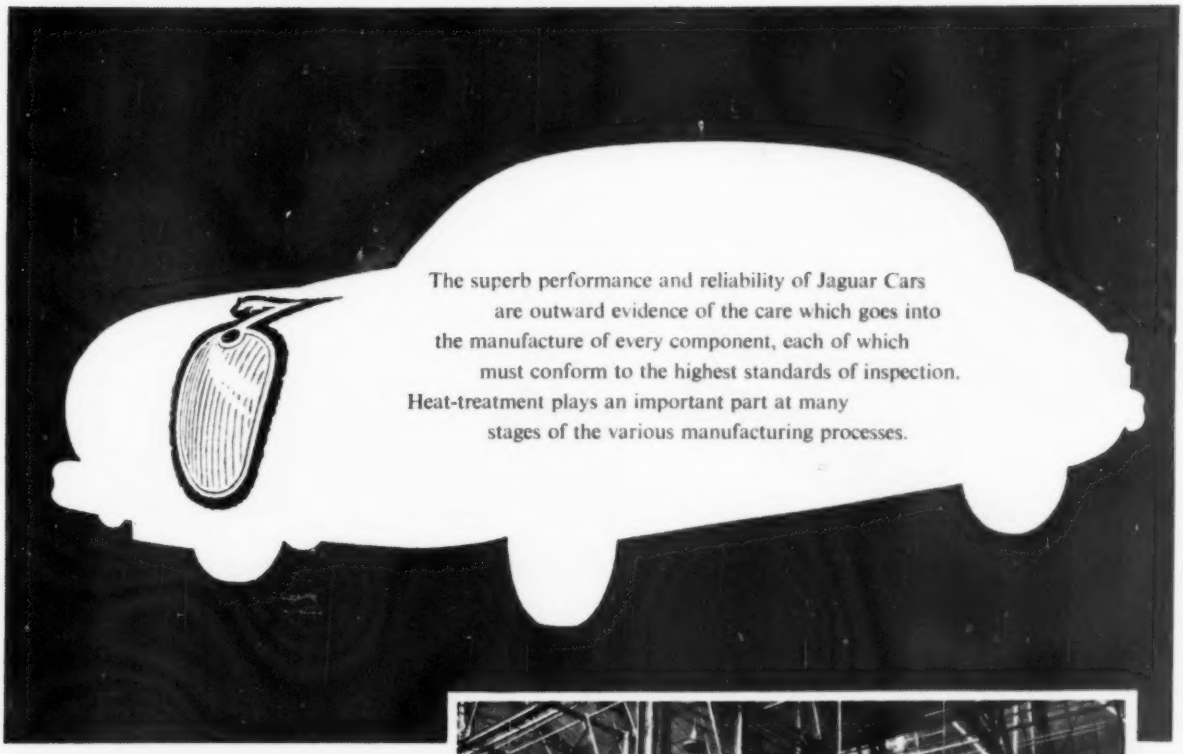
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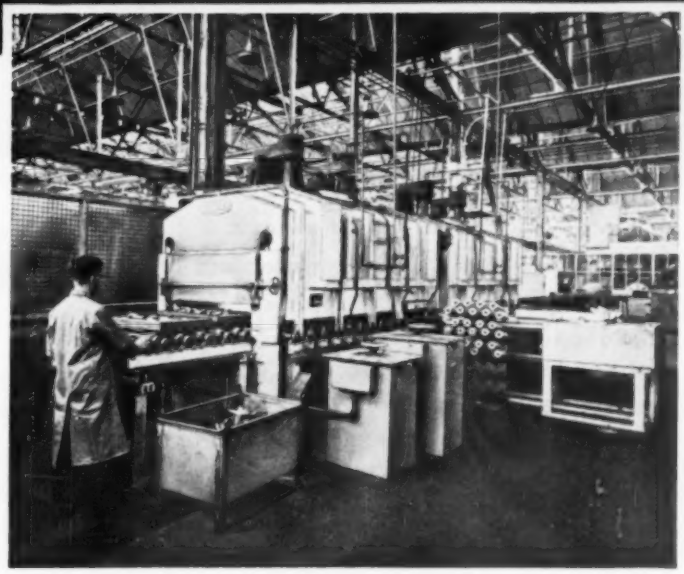

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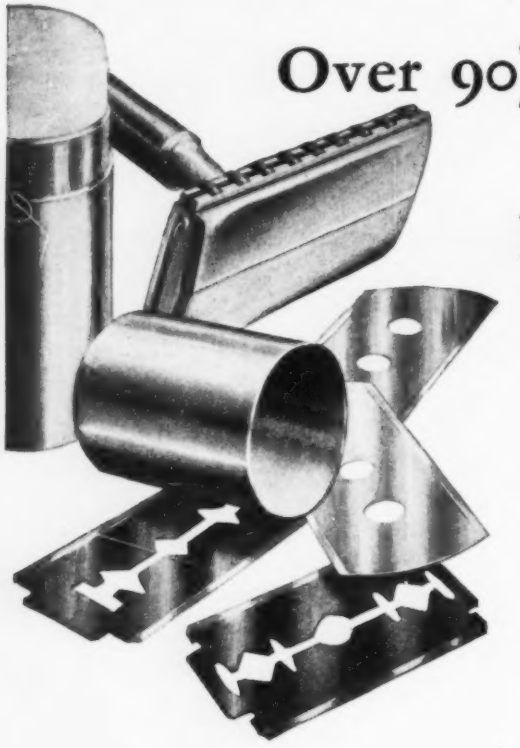

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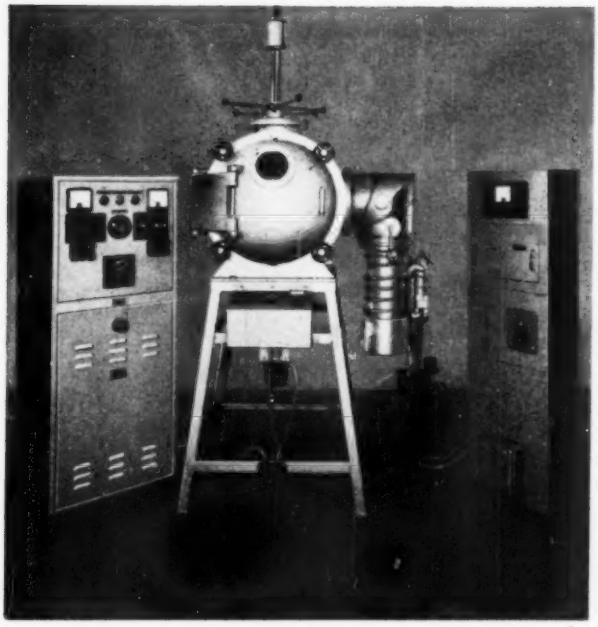

Electron beam welding carried out in high vacuum better than 10^{-4} torr (mm Hg) enables even the most *refractory metals* to be flux-free welded with complete elimination of atmospheric contamination. Unlike conventional methods the electron beam does not disturb the molten metal and thus *thin section components* can be neatly and effectively welded. The superior weld quality, deep penetration, intense localised heating and the many other advantages of electron beam welding can be fully investigated with the '**Speedivac**' unit* illustrated.

**C.E.A. System patent pending (Brit. Pat. Appl. 1962/57.)*

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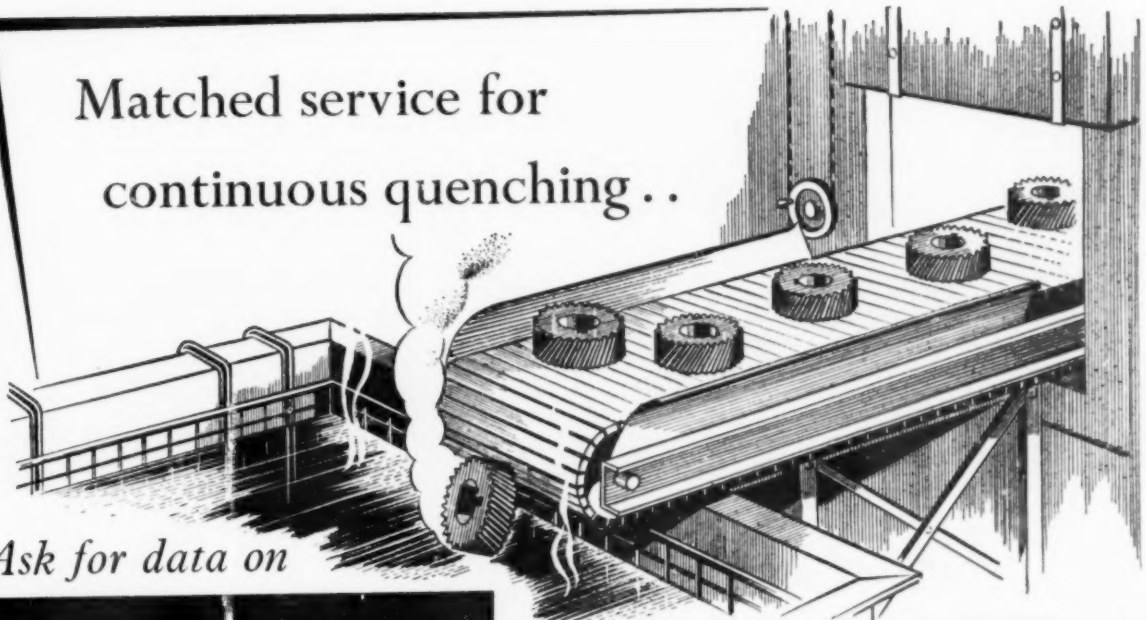

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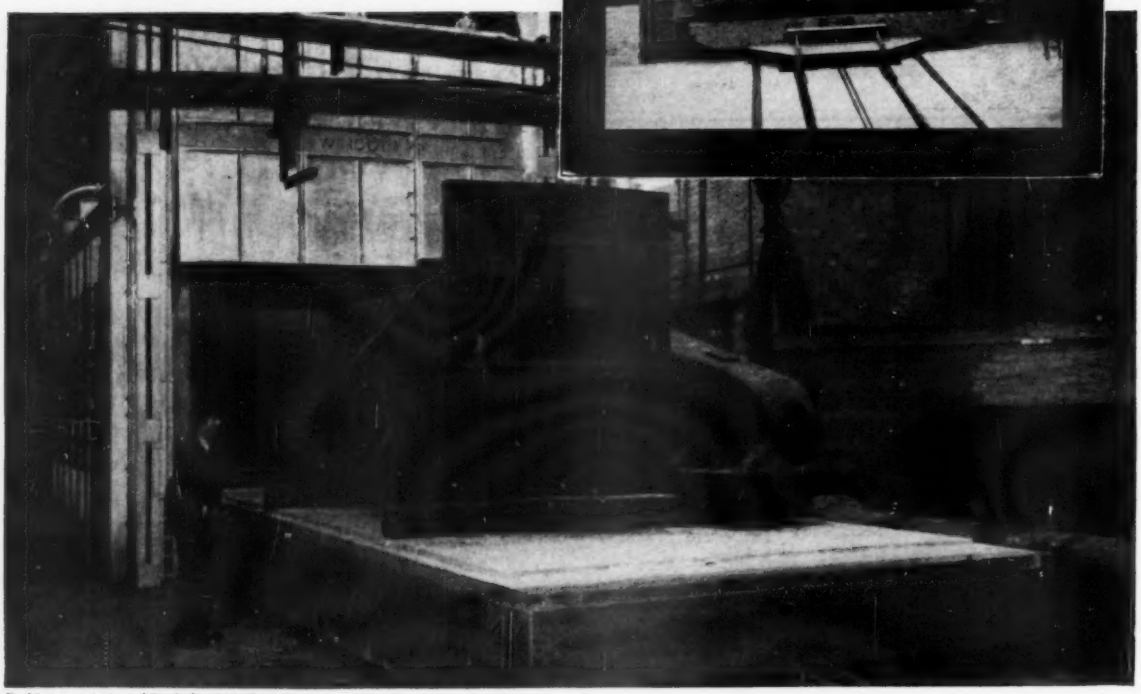

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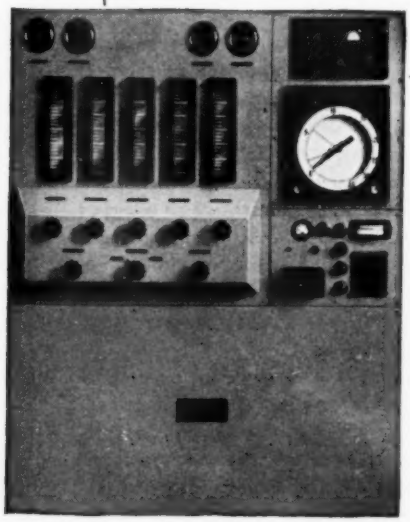

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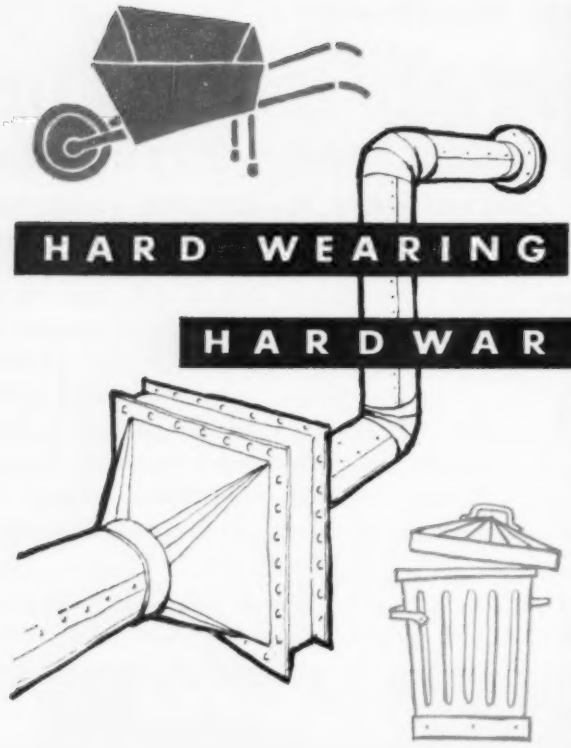

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This continuous galvanising line at the Ebbw Vale works of Richard Thomas & Baldwins Limited is the largest in Great Britain. In an average week the line produces more than 1,000 tons of Speltafast strip, which is cut automatically into sheet or can be shipped in coil form. The finished material is used for roofing and ductwork, and by manufacturers of hardware, agricultural implements, and builders' equipment.

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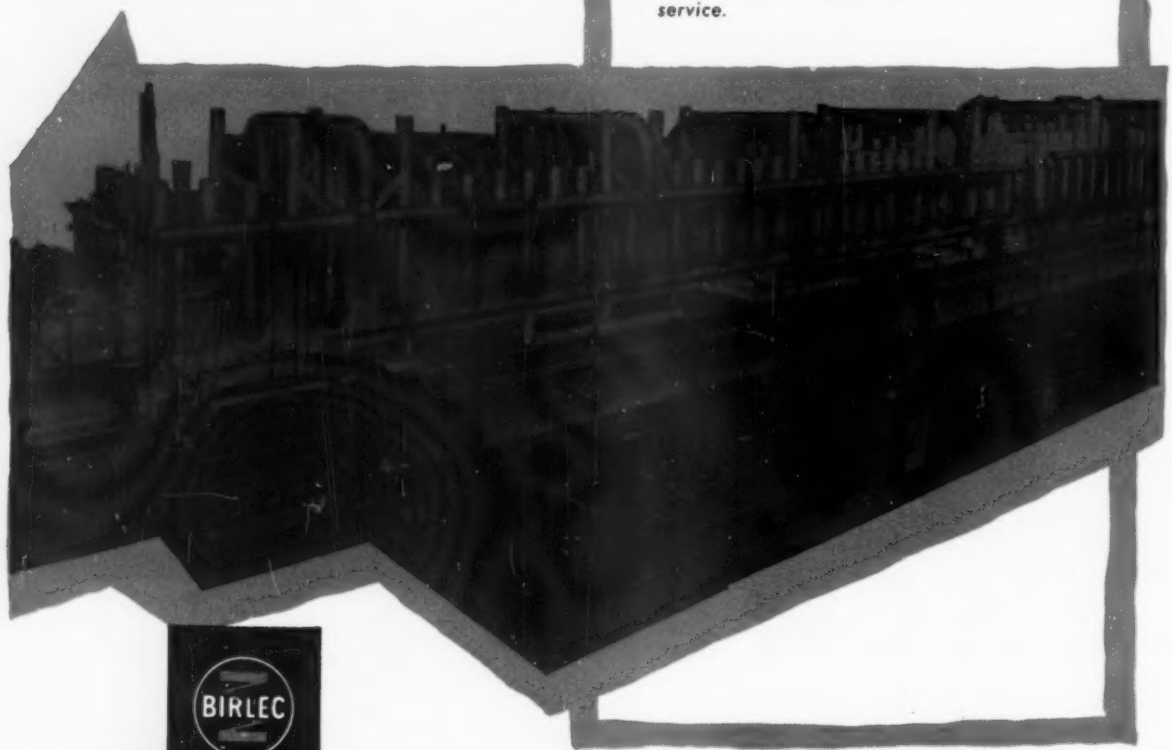

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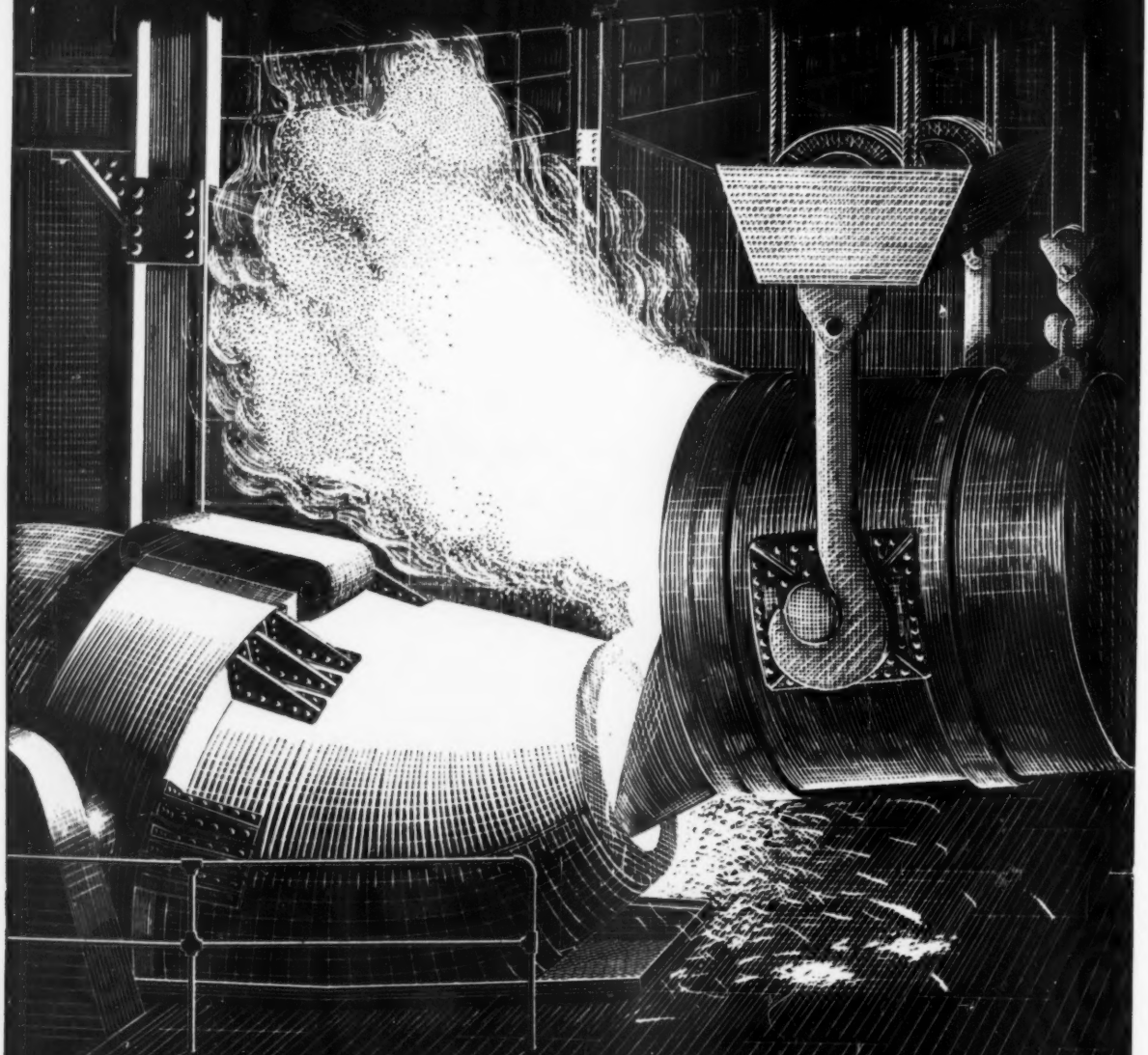

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Patent Protection in Russia

WITH increasing trade with the Soviet Union and, perhaps more important, the possibility of growing Russian competition in the export field, the regulations governing patents in the U.S.S.R. are of considerable interest. A United Kingdom delegation recently visited the Soviet Union with the object of discussing with the competent Soviet authorities the protection available in the U.S.S.R. for United Kingdom inventions. The delegation, which left London on 26th November and returned on 11th December, consisted of Mr. Gordon Grant, the Comptroller General of Patents, Mr. William Wallace, Assistant Comptroller of the Industrial Property Department, and Mr. H. R. Mathys, a Fellow of the Chartered Institute of Patent Agents and a Director of Courtaulds, Ltd. Mr. Mathys was, however, unfortunately forced by indisposition to return to London before the other members of the delegation.

The delegation had most of its discussions with what corresponds in the Soviet Union to the Patent Office, i.e., the Committee on Inventions and Discoveries under the Council of Ministers of the U.S.S.R. It also had talks with the All-Union Chamber of Commerce in Moscow which acts as an intermediary between the foreign owner of an invention and the Committee in the grant of Russian patents and, after grant, notifies the patentee of any interest shown in the Soviet Union in the use of his invention, and with the Ministry of Foreign Trade which has a general responsibility for the licensing in the Soviet Union of foreign-owned patents. A statement issued by Mr. Grant on his return from Moscow is presented here.

An inventor, Russian or foreign, has, by Soviet law, the option to seek either a patent, which gives him a monopoly in his invention which no one may then use without his permission, or an "author's certificate." In the latter case he assigns his invention to the State, which remunerates him according to the amount of use made of his invention and the resultant saving to the economy. Since the latter system involves the inventor in less expense and fits much more aptly into an economic system in which all the means of production are controlled by the State, Soviet inventors invariably seek author's certificates rather than patents. Foreign owners of inventions on the other hand tend to seek patents.

The new Soviet law of April, 1959, *so far as it concerns patents*, does not differ in its essentials from the laws of the other countries of the world. There is, of course, in the absence of *contractual* obligations, nothing to stop the copying of foreign inventions in the Soviet Union unless they are patented *there*. But the Soviet law, like those of other countries, provides the means whereby, if the necessary steps are taken, inventions can be protected. Before a patent is granted the invention must be described in a specification and a search is made through Soviet and foreign patents and technical literature to make sure that the invention is new. It must also have actual or potential "industrial utility," i.e. it must be in a field which, in the opinion of the competent Soviet technical organisation, is one in which there is or is likely to be activity. This latter test finds no place in the U.K. system, which demands instead that the invention be not "obvious." If the invention passes these tests a patent is granted and, provided renewal fees are paid each year, the patent lasts for fifteen years from the date of application. Subject to the powers reserved to the State to issue compulsory licences (on payment of remuneration to the patentee) "where an invention is of special importance to the State"—and there is something like this in the laws of most countries—it is an offence, during this period, to use the invention without the patentee's consent. The delegation was told that the patentee's monopoly embraces not only the right to prevent others from making goods incorporating the invention but also the right to prevent them from importing such goods.

If a Soviet factory wishes to use an invention the Soviet patent for which is owned by a foreigner, the latter is notified by the Chamber of Commerce. The actual contract is negotiated by the Soviet Ministry of Foreign Trade and one of the import-export corporations. The exact division of responsibility is not clear, but there is no doubt that the overall responsibility rests with the Ministry. The delegation was told of examples of licences negotiated in this way. It is usually sought to make such licences subject to arbitration before the arbitration tribunals of the All-Union Chamber of Commerce in Moscow.

On the question whether or not a patent (or author's certificate) shall be granted, the Committee on Inventions and Discoveries has the final word. The Committee has its own appeals procedures which, the delegation were told, include a right for the inventor to appear and be heard. Disputes as to the *ownership* of inventions are heard by the ordinary courts. If infringement of a patent is suspected the Committee would, it seems, look into this. In addition the delegation was told by the Ministry of Foreign Trade that infringement actions can be brought before the ordinary courts. It seems reasonable to assume, however, that no such action has ever been brought.

The Soviet officials who received the delegation expressed themselves as anxious to avoid any misunderstanding, and the discussions took place in an atmosphere of cordiality and good will. It was clear that the Soviet officials were interested in foreign patent practice and the delegation got the impression that, so far as the different economic systems permit, were tending to bring their law and practice into line with those followed elsewhere. They seemed interested in the International

Convention and had evidently given a good deal of thought to it. The delegation stressed both the practical and presentational advantages of membership of the Convention and these seemed to be understood. No indication that Soviet membership in the near future was likely was, however, given.

Little use has so far been made, by United Kingdom owners of inventions, of the Soviet Patent system, and there is therefore little practical experience. The language problem and the widely differing concepts of the rights to be enjoyed by the individual as against officials will no doubt lead to some problems. But it seems clear that, at the worst, the owners of worthwhile inventions who contemplate trading with the Russians can only lose the fees they pay and, from the assurance given to the delegation, may well have a good deal to gain if they patent these inventions in the Soviet Union. In the light of this it seems only reasonable that the Soviet system should be given a fair trial. The delegation proposes to issue a more detailed report, with a translation of the new Soviet Patent Law at a later date.

The delegation took the opportunity to discuss the protection of Trade Marks in the Soviet Union. The responsibility for this has recently been transferred to the Committee on Inventions and Discoveries. The system appears not to differ substantially from that in other countries and there is no knowledge of complaints about it. The delegation was told that several hundred British Trade Marks are registered in the Soviet Union.

Meeting Diary

2nd February

Institute of Metals: Oxford Local Section. "Some Metallurgical Factors in the Failure of Engineering Structures," by DR. L. E. BENSON. Cadena Cafe, Cornmarket Street, Oxford. 7 p.m.

Institute of Metals, South Wales Local Section. "The Use of Welded Metal," by D. L. SLATER. Metallurgy Department, University College, Singleton Park, Swansea. 6.30 p.m.

Sheffield Metallurgical Association. "Carbide Precipitation during the Tempering of Alloy Steels," by PROF. R. W. K. HONEYCOMBE. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

4th February

Institute of Metals, Birmingham Local Section. Students' Evening. College of Technology, Gosta Green, Birmingham. 6.30 p.m.

Institute of Metals, London Local Section. "Thermal Shock," by R. J. E. GLENNY. 17, Belgrave Square, London, S.W.1. 6.30 p.m.

9th February

Institute of Welding, Slough Section. "Design for Welding," by F. BROOKSBANK. Lecture Hall, Community Centre, Farnham Road, Slough. 7.30 p.m.

Sheffield Metallurgical Association. Joint Meeting with the Refractories Association of Great Britain. "Liaison between Research and Industry," by H. M. RICHARDSON. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7.30 p.m.

10th February

Institution of Plant Engineers, Dundee Branch. "Uses of Aluminium in Engineering." Taypark Hotel, West Ferry. 7.30 p.m.

Manchester Metallurgical Society. "The Precipitation Hardening Stainless Steels," by J. I. MORLEY. Manchester Room, Central Library, St. Peter's Square, Manchester. 6.30 p.m.

11th February

East Midlands Metallurgical Society. Members' Night. School of Art, Green Lane, Derby. 7.30 p.m.

Institute of British Foundrymen, Beds. & Herts. Section. "Use of Epoxy Resins for the Manufacture of Foundry Patterns," by H. G. C. KING. K. & L. Steelfounders and Engineers, Ltd., Letchworth. 7.30 p.m.

Leeds Metallurgical Society. "Flames and Furnaces," by PROF. M. W. THRING. Arrangements to be announced.

Society of Chemical Industry, Corrosion Group. "Recent Research on the Corrosion and Protection of Iron and Steel," by J. C. HUDSON. Joint Meeting with the Liverpool Section, the Liverpool Metallurgical Society and College Scientific Society. College of Technology, Byrom Street, Liverpool. 7.30 p.m.

15th February

Institute of British Foundrymen, East Anglian Section. Short Paper Competition for the L. J. Tibbenham Award. Lecture Hall, Public Library, Ipswich. 7.30 p.m.

16th February

Institute of British Foundrymen, Slough Section. "Quality in Pressure Diecasting": A Brains Trust. DR. F. M. PINOFF, P. CHAMBERS, and C. RALPH. Lecture Theatre, High Duty Alloys, Ltd., Slough. 7.30 p.m.

Sheffield Metallurgical Association. "Recent Developments in Magnetic Materials," by J. E. GOULD. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

17th February

Institute of Welding, N. & S. London Branches. "High Pressure Pipelines in the Gas Industry," by F. W. BELL. 54, Princes Gate, London, S.W.7. 7.30 p.m.

Non-Destructive Testing Society of Great Britain, Birmingham Branch. "The Principles of Weld Inspection," by DR. L. MULLINS. Engineering Centre, Stephenson Place, Birmingham. 7 p.m.

Society of Chemical Industry, Corrosion Group. "Adsorption on Electrodes and its Relation to Rates of Electrode Processes," by R. PARSONS. 14, Belgrave Square, London, S.W.1. 6 p.m.

18th February

Institute of Metals, Birmingham Local Section. "Metals and High Speed Flight," by PROF. A. J. KENNEDY. College of Technology, Gosta Green, Birmingham. 6.30 p.m.

Institute of Metals, Sheffield Local Section. Research Topics. Three short accounts of work in progress in local research laboratories. Applied Science Building of The University, St. George's Square, Sheffield. 7.30 p.m.

19th February

West of Scotland Iron and Steel Institute. "Application of Electron Microscopy in Steel Research," by F. B. PICKERING. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

22nd February

Institution of Plant Engineers, Birmingham Branch. "Modern Welding Methods," by R. T. ANDREWS. Hotel Leofric, Coventry. 7.30 p.m.

23rd February

Institution of Plant Engineers, South Wales Branch. "Metal Stitching," by N. TINWELL. South Wales Engineers' Institute, Park Place, Cardiff. 7.30 p.m.

Sheffield Metallurgical Association. "The Importance and Determination of Trace Elements in Steel," by L. KIDMAN. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

24th February

Institute of British Foundrymen, London Branch. "Modern British Bathmaking Practice," by G. R. WEBSTER. Illustrated by film. Constitutional Club, Northumberland Avenue, London, W.C.2. 7.30 p.m.

Manchester Metallurgical Society. "The Presentation of Metallurgical Information," by DR. J. W. JENKIN. Manchester Room, Central Library, St. Peter's Square, Manchester. 6.30 p.m.

Factors Affecting Temperature During the Extrusion of Non-Ferrous Metals

By A. R. E. Singer and J. W. Coakham

Department of Metallurgy, University College of Swansea

During the process of extruding a metal through a die, the heat content of the billet may be increased by such factors as friction at the metal/container interface, severe plastic deformation in the die zone, and die friction. A certain amount of this heat generation is offset by loss of heat from the billet by conduction. In this paper the authors consider the heat balance during extrusion under a range of conditions, and examine the progress made in controlling the temperature variations arising.

THE great advances in the industrial process of hot extrusion that have occurred during the last thirty years have chiefly been brought about by developments in the fields of mechanical and electrical engineering.[1,2] In contrast, the amount of fundamental work has been small and has been confined mainly to a study of flow phenomena and the calculation of energy requirements. Although it has always been recognised that temperatures of deformation during extrusion are important in determining the properties of the product, little quantitative data is, in fact, available. The reason is that the problem of heat flow in hot extrusion does not lend itself readily to investigation with small laboratory sub-presses because of their particular sensitivity to scale effects. Most attempts to obtain basic data connecting extrusion temperature with pressure have, from the early days, avoided the complexities of heat flow, and have ensured that the metal is extruded at a constant temperature throughout the process by using very low speeds of deformation.[3,4] The consequence is that while such experiments provide valuable research information, they have little direct application to industrial practice. A notable exception to this rule has been the work carried out at the Mechanical Engineering Research Laboratory* at Glasgow on the cold extrusion of aluminium and lead.[5] The purpose of the present paper is to consider the significance and the causes of temperature variations during extrusion, and to examine the progress made in controlling them on an industrial scale.

Significance of the Temperature Factor

The temperature of the billet inserted into the container has a special significance because it prescribes the starting point of the extrusion. In conjunction with the billet length, it determines the starting pressure that will be required for a given reduction, and this is normally the maximum, because pressure falls gradually during the process, except where cooling by the container is very rapid. The initial billet temperature is, therefore, always chosen so that the capacity of the press is sufficient not only to start extrusion, but also to continue at an economic speed. The preheating temperature, however, cannot be raised indefinitely for the purpose of reducing pressure or raising extrusion speed with a given press, because the properties of the product may then suffer. It is always necessary to ensure a careful compromise between economy of operation and quality of product, and the preheating temperature must be chosen accordingly.

The second factor requiring examination is the temperature of the container, pressure disc and die assembly. These items of equipment will not generally be at the same temperature as one another, but can be considered with the container for the purpose of the present argument. The container is held either at the temperature of the billet or, more frequently, at a somewhat lower level. Thus, as soon as extrusion commences, a transfer of heat to the container takes place and continues throughout the process. It is usually necessary for the extraction of heat from the billet to be kept to a minimum, and consequently the temperature of the container is raised either to a point just below that of the billet, or as high as practicable in the case of high temperature metals and alloys where, from strength considerations alone, the container temperature is necessarily many hundreds of degrees below that of the billet.

The place at which temperature is of the greatest significance during extrusion is within the billet, especially in the region of the die orifice. In this region large quantities of heat are generated as a result of the plastic deformation taking place. At the same time heat is extracted partly by conduction to the container and die assembly, and partly by conduction back through the billet to the cooler part remote from the die. The final result may be either a raising or a lowering of the temperature of metal in the die region, depending on the speed at which extrusion is being carried out. The passage of the metal through the die region leads ultimately to the extrusion emerging from the die, and because of the inhomogeneous deformation pattern and the complex heat balance referred to above, it will emerge with a variation of temperature across its section. Except in complex extruded sections, the temperature difference across the section is usually not large compared with that along its length, and in the present paper no special consideration is being given to this aspect of temperature variation. It should be noted, however,

* Now the National Engineering Laboratory

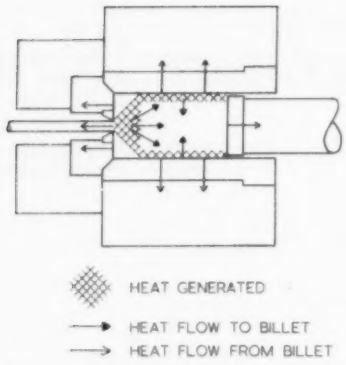


Fig. 1.—Heat distribution during extrusion.

that it is the highest temperature attained in any part of the extrusion that is of greatest importance in determining its properties and behaviour. This most frequently occurs at or near the surface, or in the case of complex sections, where the deformation has been most severe. If we ignore the effects of friction of the billet on the container wall, then the thermal conditions in the region of the die determine the pressure required for a given speed of extrusion, and *vice versa*. As these conditions also determine the emergent temperature, we can expect them to be closely related to the pressure required and the speed of extrusion obtained. The emergent temperature is the outcome of the interaction of all the variables so far mentioned, and is a factor having a direct bearing on the properties of the product.

Deformation of the metal in the region of the die causes considerable variation of stress and flow velocity, leading, in some cases, to two main types of cracking defect : these are the central cracks formed in the region before the die orifice and the familiar peripheral cracks at the die exit.[6] For this reason it is necessary in the case of hot-short alloys that temperatures in the die region should be appreciably below the solidus. At the other extreme, too low an extrusion temperature is associated with low temperatures adjacent to the die orifice, and therefore with high extrusion pressures and low speeds of extrusion which, carried too far, may halt the process so that the billet has to be discharged.

Within these limits the properties of the product vary according to the temperature at which it issues from the die. For example, during the extrusion of certain $\alpha + \beta$ brasses, too high a temperature may lead to a coarse-grained β structure containing acicular α constituent, and too low a temperature may yield an elongated β structure containing banded masses of α which is liable to fracture on subsequent hot working. Moreover, when the temperature rises too high, which in the case of copper alloys is normally in the early stages of extrusion, incipient melting may occur ; metal then builds up on the die, where it causes the rod to emerge with a grooved surface and below the expected diameter.[7] Dimensional tolerances also have to be taken into account because a variation of temperature along the length of an extrusion will lead to differences in the final dimensions of the product after cooling, when thermal contraction has taken place.

Titanium rods extruded in the α region exhibit higher yield and ultimate strengths than those extruded in the β region. Extrusion of a titanium alloy containing 3% manganese and small quantities of chromium, iron, molybdenum and vanadium showed that even though the original billet temperature was in the $\alpha + \beta$ region, the temperature rise at the beginning of extrusion was sufficient to transform the alloy to the all-β region. Rods extruded at higher temperatures fractured in a brittle manner, probably because of their coarser grain size.[8]

Magnesium alloy extrusions sometimes have a higher strength in tension than in compression in the extrusion direction, presumably because deformation can take place by twinning in compression but not in tension.[9] Twinning, however, is much more difficult with a fine-grained material, so that if a high compressive strength in the direction of extrusion is required, the metal is extruded at a low temperature and speed, and quenched at the die. Generally speaking, the highest permissible temperature and speed are preferred with magnesium alloys in order to avoid excessive grain growth on heat treatment.

In a related field, Cole[10] reports that smooth extrusions of good mechanical properties can be made from magnesium powders, provided the billet temperature exceeds 470° C. Brown[11] reports that satisfactory extrusions were made from compacts of the same powder with billet starting temperatures as low as 300° C. His speeds of extrusion were much higher, however, and it seems that the temperature rise during extrusion was sufficiently great to compensate for the low initial temperature.

In the case of some strong aluminium alloys, extrusion at the lowest practicable temperature may cause exaggerated grain growth after heat treatment, and to a destruction of the enhanced mechanical properties that are such desirable feature of the alloys, while too high a temperature may lead to local overheating which causes blistering during heat treatment, or may lead to hot-shortness.[7] Nowadays some aluminium alloys, especially those based on magnesium silicide, are heat treated by quenching directly from the die. In this case a precise control of the emergent temperature would be of great benefit in ensuring that the product meets specification on mechanical properties.

For the reasons outlined above it is obviously most important to be able to control the temperature of the emergent extrusion so that it remains substantially constant at the desired value. However, the heat balance within the metal billet during extrusion is so complex that unless the process is controlled with the utmost care, based on technical knowledge, it is unlikely that the emergent temperature will be constant.

Heat Balance During Extrusion

In the hot extrusion process, in addition to the original heat content of the billet, further heat is supplied in three main ways. In the case of direct extrusion it is generated by movement of the billet along the container as extrusion proceeds, and it may be considered to be caused either by friction at the interface, or by shear of the metal under the skin of the billet adjacent to the wall. Heat is also generated in the die zone as a result of the severe plastic deformation occurring in this region. The third source of heat is die friction.

Heat generated by movement of the billet along the container during extrusion will, to some extent, offset the loss of heat from the billet by conduction. As a first

approximation both effects are proportional to the length of the remaining unextruded portion of the billet so that they may, with convenience, be considered together. It is to be observed that the total amount of heat generated by shear or friction is, for practical purposes, independent of speed, whereas the heat loss to the container by cooling is inversely proportional to the speed of extrusion. The net result is that the unextruded portion of the billet either heats up or cools down during the process, according to which factor plays the more prominent part. This heat exchange is important because it helps to determine the temperature of metal entering the die zone. Thus, raising the speed of extrusion leads to roughly the same amount of heat being generated by shear or friction, but causes a reduction in the loss of heat by conduction to the container.

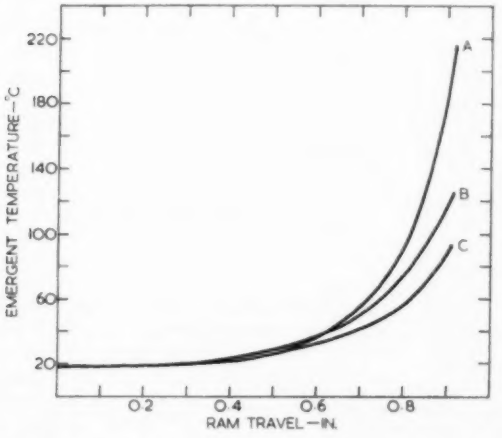
The heat generated by die friction may raise the temperature of the surface of the emergent extrusion slightly, but that generated by plastic deformation in the die region is usually so great that the effect of die friction is unimportant by comparison, and in some circumstances the cooling effect of the land of the die may be greater than the heating effect.

Most of the heat generated during extrusion appears in the deformation zone adjacent to the die, and the quantity of heat and the way in which it is partitioned have a large effect on the emergent temperature. Fig. 1 illustrates the pattern of heat flow and shows diagrammatically how the heat generated at various points in the billet is distributed.

The M.E.R.L. experiments were carried out on the direct cold extrusion of lead and aluminium. Thermocouples were inserted at known positions in the billets and the temperatures they registered were recorded as extrusion proceeded.[5] It was shown that temperature rises of the order of 100–200° C. occurred in the die orifice. All the experiments were carried out at constant speed and the complex heat-flow pattern typical of hot extrusion was avoided by using billets at room temperature. The results reproduced in Fig. 2 show clearly how the temperature of metal rises as it passes through the zone adjacent to the die. From work carried out by Johnson,[12] and Wilcox and Whitton,[13] relating the pressure necessary for deformation at the die to the amount of reduction, and by Watkins *et al*[5] and Asheroft and Lawson[14] relating the maximum pressure required to this variable, it appears that the total heat generated is given in its simplest form by an equation of the type :

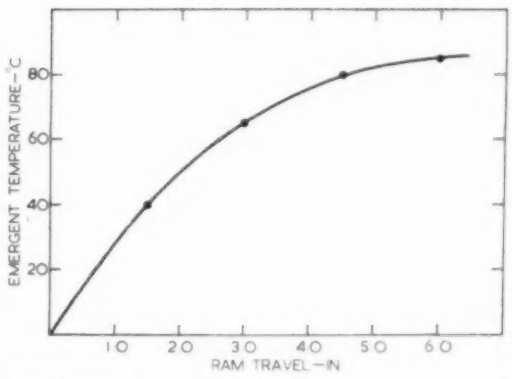
$$\text{Heat generated} = k_1 + k_2 \log_e \frac{A}{a}$$

where k_1 and k_2 are the appropriate constants and $\frac{A}{a}$ is the extrusion ratio. A proportion of the liberated heat is available for raising the temperature of the extrusion, and it can be seen from Fig. 2 that the final temperature recorded increases with the speed of extrusion. Despite the very modest extrusion pressures used, the temperature rise is substantial.



Reduction (%)	99·4
Ram speed (in./min.)	
A	27·5
B	13
C	1

Fig. 2.—Effect of ram speed on temperature rise in chemical lead : thermocouples on centre line and ½ in. deep (Watkins et al.)

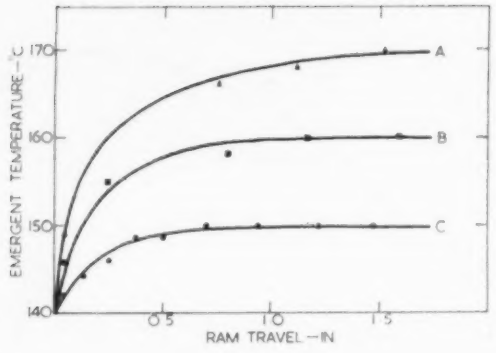


Billet width (cm.)	15
Reduction (%)	66·7
Ram speed (cm./sec.)	5

Fig. 3.—Temperature rise in plane strain extrusion of copper.

In this connection a much more accurate theoretical investigation by Bishop[15] has shown how the temperature in the die zone can be expected to rise at the beginning of the cold plane strain extrusion of copper in a steel container. Although this may be far removed from industrial extrusion, it has shown clearly that a considerable temperature variation is to be expected in the die region as extrusion proceeds. Values of the average temperature of the extrusion emerging from the die have been taken from Bishop's calculated diagrams and are reproduced in Fig. 3. It is seen that under the simplest conditions of an insulated container at the billet temperature, a constant speed and a constant yield stress, the emergent temperature must rise as extrusion proceeds.

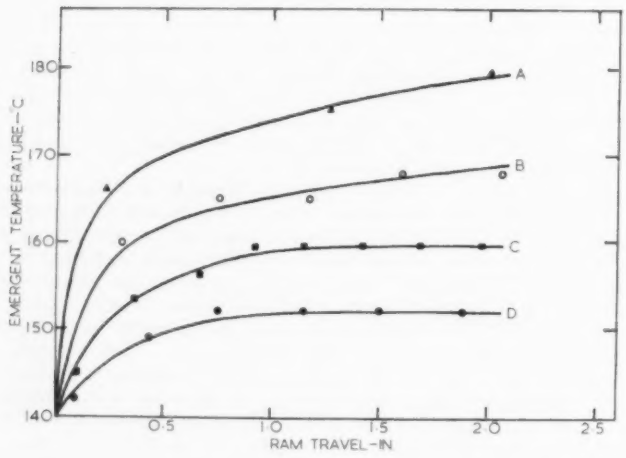
Work has been carried out by the authors to show the way in which the emergent temperature varies during the hot extrusion of various metals from small containers held at constant temperature. The temperature was that of the surface as it emerged from the die, because this offered a practically accessible point for measurement. It was made by pressing two pointed probes, one of Chromel and one of Alumel, into the extrusion, and the e.m.f. generated by the thermocouple was then



Container temperature (° C.)	140
Billet temperature (° C.)	140
Billet length (in.)	2
Billet diameter (in.)	1
Reduction (%)	93·75
Ram speed (in./min.)	
A	10
B	5
C	2

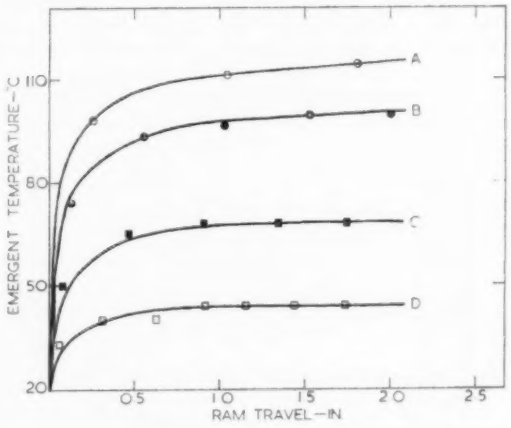
Fig. 4.—Effect of ram speed on emergent temperature of lead extrusion.

fed into a high speed recorder. The probes were maintained in contact with the extrusion as it moved away from the die for a minimum of one second in order to obtain a reliable measurement of temperature. The probes were then withdrawn and re-inserted at a new position on the rod near the die orifice. In this way a series of readings of the emergent temperature was made at intervals of a few seconds. Figs. 4 and 5 show the results obtained when using containers of 1 in. and 2 in. diameter respectively, with lead at 140° C., and Fig. 6 shows the results with the 2 in. diameter container at 20° C. It can be seen that the temperature rise for the same speed and reduction is greater at the lower starting temperature by virtue of the greater pressure needed for deformation. Fig. 7 shows the results on tin at 20° C. and Fig. 8 those on aluminium at 260° C., using a container 1½ in. in diameter. In all cases the emerging surface temperature rises in a similar way to Bishop's average values and, therefore, serves as a good indication of the temperature conditions in the die region. There are many reasons for the temperatures rising in the observed manner. Firstly, in the early stages of extrusion the metal emerging from the die receives increasing amounts of deformation, and most of the work done on the metal becomes available as heat energy, until all the material originally in the deformation zone is extruded. Secondly, although part of the heat generated in the die region passes into the extrusion, thus raising its temperature, the remainder is conducted back to the unextruded billet, causing a rise in temperature here also. Thus, the next portion of metal entering the die zone starts at a higher temperature than the first, and therefore leaves the die at a still higher one. The unextruded portion of the billet is also heated by the frictional heat generated at the billet/container-wall interface. The proportion of the total heat generated which is conducted to the unextruded portion of the billet



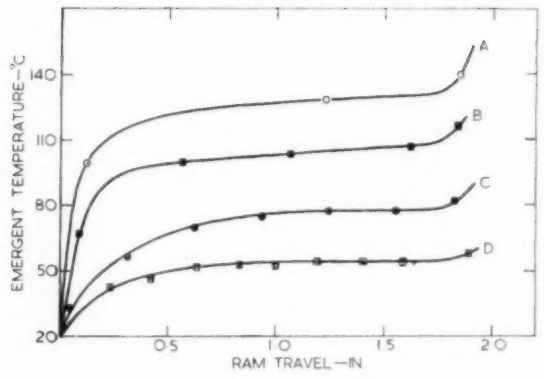
Container temperature (° C.)	140
Billet temperature (° C.)	140
Billet length (in.)	2·5
Billet diameter (in.)	2
Reduction (%)	93·75
Ram speed (in./min.)	
A	30
B	10
C	4
D	2

Fig. 5.—Effect of ram speed on emergent temperature of lead extrusion.



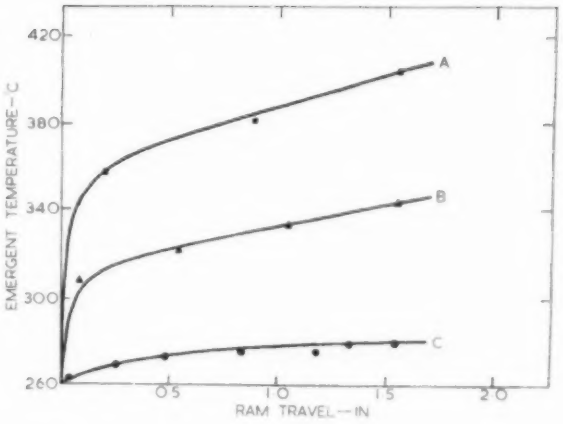
Container temperature (° C.)	20
Billet temperature (° C.)	20
Billet length (in.)	2·5
Billet diameter (in.)	2
Reduction (%)	93·75
Ram speed (in./min.)	
A	30
B	10
C	3
D	1

Fig. 6.—Effect of ram speed on emergent temperature of lead extrusion.



Container temperature (° C.)	20
Billet temperature (° C.)	20
Billet length (in.)	2
Billet diameter (in.)	1·5
Reduction (%)	93·75
Ram speed (in./min.)	
A	30
B	10
C	3
D	1

Fig. 7.—Effect of ram speed on emergent temperature of tin extrusion.



Container temperature (° C.)	260
Billet temperature (° C.)	260
Billet length (in.)	2
Billet diameter (in.)	1·5
Reduction (%)	93·75
Ram speed (in./min.)	
A	30
B	10
C	1

Fig. 8.—Effect of ram speed on emergent temperature of commercially pure aluminium extrusion.

depends on the thermal diffusivity of the billet material, and this affects the way in which the emergent temperature varies throughout extrusion. It can be seen from Figs. 4–8 that in the case of aluminium, for example, the rise in temperature along the length of extrusion, after the material originally in the deformation zone has been extruded, is greater than that of tin or lead by virtue of its larger thermal diffusivity. At the end of extrusion, when the pressure rises, the emergent temperature rises also, and this can be seen in Fig. 7. The other extrusions were stopped before the pressure rose significantly. Figs. 4–8 also illustrate clearly the higher temperatures associated with the greater speeds of extrusion.

Some further experiments were carried out on the extrusion of an impure tin, which at elevated temperatures exhibits hot shortness.[16] Fig. 9 is a photograph of this sample of tin extruded at a constant speed of 10 in./min. from an insulated container at 207° C. and with an extrusion ratio of 25. Surface fracture is seen to commence about one quarter of the way along the length, and to increase markedly towards the end at the outside of the spiral; this shows convincingly the rise in emergent temperature that occurs during the process when operating at constant speed and negligible heat loss. Extruded under the same conditions, but at 2 in./min., the tin did not exhibit high temperature embrittlement. The temperatures associated with these two velocities are shown in Fig. 10.

Increasing the speed of extrusion causes a slight rise in the total quantity of heat produced because of the increase in yield stress and hence in extrusion pressure, with rate of strain, and also a greater proportion of heat is carried forward with the extrusion as compared with

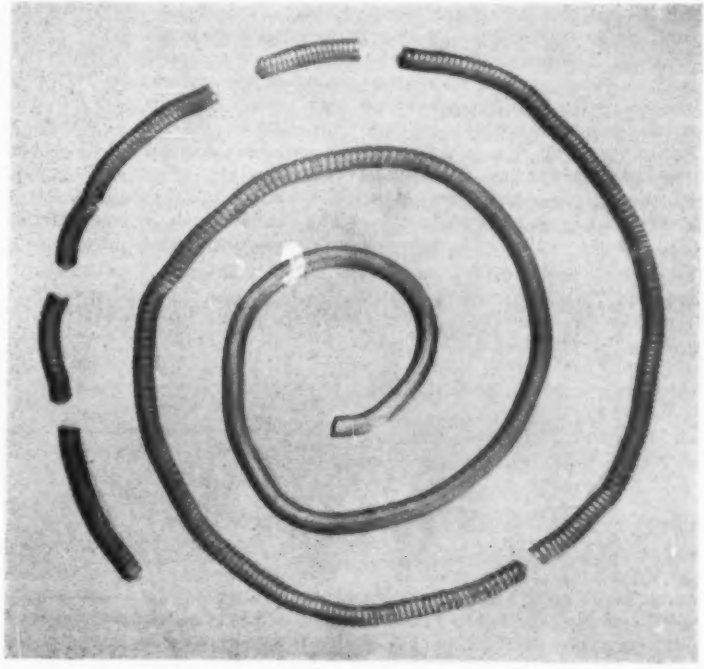
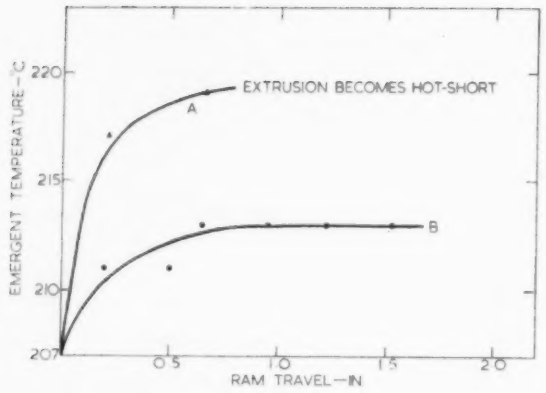


Fig. 9.—Extrusion of hot-short tin at constant speed.



Container temperature (° C.)	207
Billet temperature (° C.)	207
Billet length (in.)	1·75
Billet diameter (in.)	1·25
Reduction (%)	96
Ram speed (in./min.)	
A	10
B	2

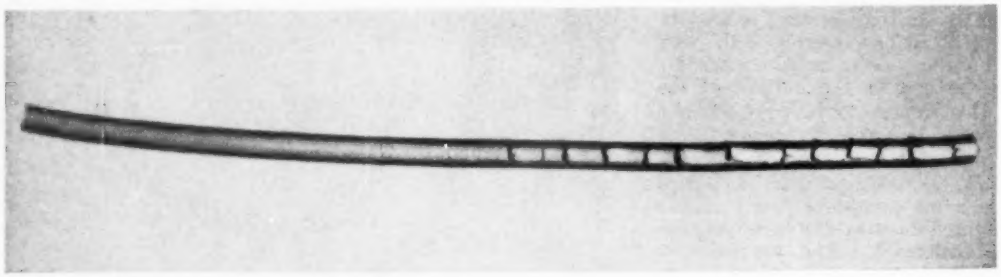
Fig. 10.—Effect of ram speed on emergent temperature of tin extrusion.

that conducted back into the unextruded portion of the billet and the extrusion tools. The emergent temperature of an extrusion made at a greater speed is for these reasons higher than that at the low speed. The effect is, of course, a familiar one in industry, and a typical example is illustrated in Fig. 11, which shows the hot-short surface cracking that occurred when the speed was increased during the extrusion of a duralumin-type alloy.

In the case of much industrial extrusion, the billet is pre-heated to a higher temperature than the container, and consequently loses heat continuously during the process. The heat balance in this case is quite complex, and in order to gain an understanding of the process the following simple experiment was made: A 1 in. diameter experimental container was allowed to cool while the billet was being extruded, and heat was extracted from it at an appropriate rate. The total effect on the extrusion bears some similarity to what would be expected on an industrial scale. The curves given in Fig. 12 were obtained in our laboratories during the extrusion of lead, and show how the surface temperature of the emergent extrusion varies with ram travel at four different speeds. In each case the initial billet and container temperatures were 140° C., and from the commencement of extrusion the container was allowed to cool at a known rate. At high speed the time available for cooling of the billet is small, heating effects therefore exceed cooling effects throughout the process, and the emergent temperature rises continuously. At very low rates of extrusion the reverse is true and the emergent temperature drops throughout. The heating effects exceed the cooling effects during the earlier part of extrusion at intermediate speeds, and the emergent temperature rises at first, although later in the process cooling of the billet becomes predominant, the emergent temperature stops rising and then falls progressively until the end of the process.

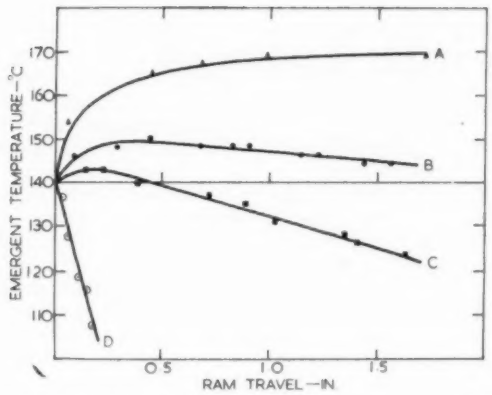
A further series of experiments was carried out to determine the temperature variation when a hot billet was extruded from a cooler container in an attempt to simulate industrial practice. The results obtained during the extrusion of a lead billet at a temperature of 120° C. from a 2 in. diameter container at room temperature for various speeds is shown in Fig. 13. It will be seen that the same general shapes are obtained as before, although modified by various factors not considered in the earlier case. The rate of cooling is very much greater in this case, and the speed at which the emergent temperature falls throughout the whole of the process and that at which it rises throughout the process are raised. Extrusions carried out at the lower speeds also reveal that the rate of cooling towards the end of extrusion is greatly diminished and is balanced by the slight heating effects. Additionally, it will be noted that the temperature rises rapidly at the end of extrusion when the ram destroys the zone of deformation and causes a rise in pressure. The above general pattern is similar to that of many industrial extrusions. Where the temperature of the billet is far higher than that of the container, as in the case of many copper-base alloys, then high extrusion speeds will be necessary to prevent a continuous fall in temperature. Such high speeds of operation may not, of course, be practicable with many existing industrial presses.

The emergent temperature and the temperature in the region of the die are therefore the results of the interaction of a large number of variables and will alter considerably during the course of extrusion, even when a constant ram speed is maintained. When speed changes



Direction of Extrusion

Fig. 11.—Hot-short cracks caused by a rise in extrusion speed.



Container temperature (initial, ° C.)	140
Billet temperature (initial, ° C.)	140
Billet length (in.)	2
Billet diameter (in.)	1
Reduction (%)	93·75
Ram speed (in./min.)	
A	10
B	2
C	0·5
D	0·05

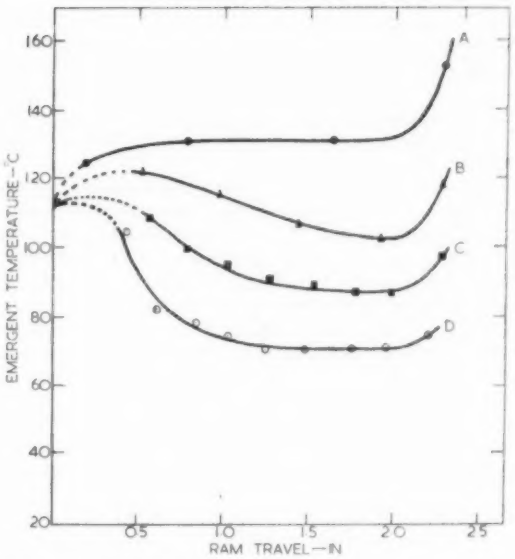
Fig. 12.—Effect of ram speed on emergent temperature of lead extruded from a cooling container.

occur during extrusion, the problem becomes much more complex and the result is difficult to predict with accuracy.

Measurement of Emergent Temperature

The importance of ensuring that the emergent temperature is constant is so great that it would be advantageous if measurements could be made continuously during extrusion. The problem in its simplest form resolves itself into the possibility of measuring the surface temperature of the extrusion as soon as it emerges from the die, because this acts as a guide to the conditions immediately before the die orifice. The essential requirements of an instrument for this purpose are that it must be sensitive to temperature within the operating range and capable of giving an accurate reading. It must have a high speed of response and must be readily applied at the appropriate point without interference to the process. Traditional methods of temperature measurement by means of thermocouples may be adapted for this purpose and a variety of mechanisms have been devised, ranging from fine dragging thermocouple wires and spiked wheels to the use of the extrusion and the die as a thermocouple pair in much the same way as has been done during wire drawing.[17] Although these methods may be excellent for research purposes, they are not well suited for industrial use because of their interference with the process and the damage imparted to the surface of the product. Radiation methods are probably the most interesting from the point of view of use in industry, because they can be designed to give a high response without having physical contact with the extrusion. Either total radiation pyrometers using high response thermopiles or photoelectric pyrometers are suitable for such measurements. The lead sulphide cell seems to be specially applicable at lower temperatures, in view of its sensitivity to infra-red radiation and its low response time.

The potential value of a measurement of temperature is greatest with some of the aluminium alloys, and it is



Container temperature (° C.)	20
Billet temperature (° C.)	120
Billet length (in.)	2·5
Billet diameter (in.)	2
Reduction (%)	93·75
Ram speed (in./min.)	
A	30
B	10
C	5
D	2

Fig. 13.—Effect of ram speed on emergent temperature of hot lead billet extruded from a cold container.

particularly unfortunate that these alloys have very low emissivities, varying according to surface roughness and the thickness of oxide film present. Moreover, they do not behave as " grey " bodies ; that is, their spectral emissivity varies with wavelength.[18] Several methods of temperature measurement have been devised to overcome these difficulties. Total radiation pyrometers using reflecting hemispheres[19] are an attempt at making the effective emissivity of a surface as near to unity as possible. The emissivity of an extrusion of an aluminium alloy is, however, very low and varies according to a number of operating factors. Together with the inherent inaccuracies of the pyrometer—such as radiation losses—and the necessity of maintaining a surface of very high reflectivity, these facts make it unsuitable for use with aluminium alloy extrusions. Two-colour pyrometers have been devised so that they are substantially independent of emissivity,[20] but they only possess this quality provided two wavelengths with the same spectral emissivity are compared. This presents obvious difficulties when using the instrument to measure the temperature of " non-grey " bodies. The problem is, therefore, a very difficult one, and the production of an instrument to give a satisfactory performance under industrial conditions is still awaited.

Controlling the Emergent Temperature of Extrusion

Progress in the control of emergent temperature has been greatest with the aluminium-base alloys, for the simple reason that it is easier to achieve an approximate balance of the various heating and cooling effects. With high temperature alloys it is difficult, and in many cases

impracticable with existing equipment, because of the drastic chilling effects of the container on the hot billet. Consequently, most advances are likely to occur in the immediate future in the field of the aluminium-base alloys. However, the principles are the same for all non-ferrous metals, and with suitable equipment, should be applicable to the more refractory high temperature alloys.

Two main ways of ensuring that the emergent temperature approximates to what is required present themselves for consideration. In the first place, each factor contributing to the process can be standardised at an optimum value, determined beforehand by practical experiment, so that if the operation goes according to schedule, the extrusion emerges at a known temperature, or with a known range of temperature. This method is the one that has been developed gradually since the origin of the process and has culminated in the automatic extrusion press. A second method, still largely undeveloped, is one which may become increasingly important to industry in the future. It involves controlling the temperature of the emergent extrusion dynamically by detecting temperature errors and correcting them by an alteration to one or more of the variables of the process, using a closed loop control.

The standardising of variables is a well advanced technique and is widely used in industry. In a typical case the billet is placed in the container at a standardised temperature, higher than that of the container, and extruded at a constant velocity. During extrusion the billet loses heat by conduction to the container, but at the same time is heated by conduction from the various thermal sources mentioned earlier. To some extent, therefore, by a judicious choice of temperature and velocity, a balance can be contrived between the heating and cooling effects to keep temperatures within reasonable limits. From the results shown in Figs. 12 and 13, however, it is not to be expected that a constant speed of extrusion will produce a standardised emergent temperature, and this is in accordance with practical observations. To overcome the difficulty, extrusion presses have been designed which operate on a speed programme. If, for example, under certain standard conditions the billet is known to heat up during extrusion, the speed programme is arranged so that the velocity during the latter part of the extrusion is lower than at the beginning. Thus, a three-step programme of speed often gives a product having a smaller temperature variation and more uniform properties than a single speed. A well designed smoothly graded speed programme, though more difficult to arrange, will give even greater uniformity in the final product. A different method of overcoming the problem of rising temperature during extrusion is to use taper-heated billets[21] and much progress has been made in perfecting low- and high-frequency preheating equipment for this purpose. Billets possessing the correct temperature gradation along their length will compensate for the temperature rise that would otherwise occur towards the end of extrusion by feeding cooler metal into the die zone as extrusion proceeds. The success of all these methods depends on keeping the working conditions and a particular sequence of events rigidly constant, and it can therefore be offset by any slight departure from standard procedure. It is for this reason that semi-automatic or automatic operation is such an advantage, as the human factor responsible for so many small variations in practice is substantially eliminated. The results of such automatic processes are highly satisfactory, provided always that the correct sequence and timing of operations are prescribed and followed rigidly. In this sense it is a static form of control and cannot readily compensate for irregularities caused by the chance fluctuations always present in industrial processes, nor is it easily adaptable to different alloys.

An alternative control of a dynamic type could be obtained by measuring the actual emergent temperature, comparing it with the desired temperature standard, and then altering the process in order to correct the observed error. A very simple form of such a closed-loop control has for many years been a common feature of the extrusion of light alloys liable to crack by becoming hot-short. In this case the press driver observes the surface of the extruded product and at the onset of hot-shortness, reduces the extrusion speed. It is, of course, of limited value as the first indication of error involves the scrapping of part of the extrusion, but the principle is an important one. Using variation of extrusion speed as a means of correcting errors in the emergent temperature seems to be practicable within certain limits, because, as described earlier, high speeds of extrusion cause a rise in the emergent temperature, and *vice versa*. In practice the feasibility of such a control system depends upon the rapid measurement of the emergent temperature, on the effectiveness of corrective action within the limits of speed that are practicable on the extrusion press, and, most of all, on the variation of the function relating a change of temperature to a change of speed. The rapid and reliable measurement of emergent temperature and the effectiveness of corrective action are matters that need considerably more scientific investigation. It is clear that there will be limits to the amount of correction achievable, set by the capacity of the press, the temperature gradients existing in the metal during extrusion, and the way in which the gradients are affected by an alteration to the speed of the process. A major advance would be made if a form of closed loop control could be developed. However, it is not suggested that this should necessarily replace the existing methods of standardising the cycle of operations, rather it should be used in conjunction with it. It might then be possible to make corrections for the fortuitous variations always found in industrial practice, and as a result of diminishing the margins of error, maximum permissible rates of extrusion with all their attendant benefits could then be obtained throughout the process.

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Copper and Copper Alloys

A Survey of Technical Progress During 1959

By E. Voce, Ph.D., M.Sc., F.I.M.

Copper Development Association

Continued progress has been made in the past year in the metallurgy of copper and its alloys, and in the various sections of this review the author discusses the principal items of interest concerning such aspects as extraction, fabrication, finishing, properties and testing.

REGULAR readers of this series of reviews of copper and copper alloys may find that the present contribution differs in character from its predecessors. Though it ranges broadly over the same field, it has become more selective and informative, attention being concentrated on publications which seem to offer some definite contribution to metallurgical knowledge, as distinct from review articles and similar material. The improvement has been made possible through the publication by the Copper Development Association of a monthly series of *Copper Abstracts* which provide the wide coverage hitherto afforded by the surveys alone. It is hoped that the change will be approved, and that the scope of the review will be found adequate.

The Production of Copper

Hydrometallurgy

Mancke and Temmel[1] have patented a process for the recovery of copper and cobalt from calcined pyrites. The calcine is acid-leached under oxidising conditions at elevated temperature and pressure to dissolve the non-ferrous metals and some iron. The *p*H of the solution is adjusted to between 2·0 and 2·6 by adding calcium or magnesium carbonate, and copper is precipitated as the sulphide by means of sulphuretted hydrogen or sodium sulphide. Iron and cobalt are recovered subsequently. Govorov[2] has investigated the possibility of separating iron from non-ferrous metals in copper-nickel mattes after leaching with sulphuric acid without an autoclave. He claims to have developed a process which separates all the copper in the form of a sulphide concentrate.

The influence of various factors on the rate of dissolution of copper and cobalt sulphides in solutions of ammonia under oxygen pressure has been examined by Naumov and Tseidler.[3] They found that high rates of copper and cobalt extraction could be achieved by increasing the pressure of oxygen, the concentration of ammonia in the solution and the temperature of operation, but that stirring rate had little effect on the results.

According to Franklin,[4] preliminary work has been undertaken by the Kennecott Copper Corporation with a view to developing a process for the bacteriological leaching of low-grade copper sulphide ores. More may be heard of this project in the future.

Roasting

Henderson[5, 6] has published two papers on the oxidation of mixed copper and iron sulphides in the form of lumps[5] and cylindrical powder compacts,[6] respectively. In both cases, not only ferrous sulphide and cuprous sulphide, but also a number of mattes and mineral copper-iron sulphides were used for the experiments. At temperatures above 600° C., oxide layers formed most readily on cuprous sulphide and on mattes of very high copper content, and most slowly on mattes containing about 66% of copper. He also observed that sulphides prepared by fusion under air oxidised more rapidly than those prepared under nitrogen, while mineral sulphides oxidised at an intermediate rate. Sulphate remains the primary oxidation product of ferrous sulphide, even at temperatures where the sulphate is unstable, but the sulphate so formed rapidly decomposes into ferric oxide. In contrast, cuprous sulphide oxidises directly to cuprous oxide, with subsequent further oxidation to the cupric form.

Converting

Based on plant experience and a review of literature, Iolko[7] has put forward certain recommendations to gain efficiency in copper converting practice. He maintains that the process should not be intensified by increasing the blast pressure or temperature, and to this end favours a maximum number of tuyères with minimum air pressure and a large throat for the converter. Nevertheless, he makes a strong plea for the adoption of oxygen-enriched blast. Also from Russia come details of laboratory and pilot plant furnace installations for the continuous conversion of copper mattes.[8] Blast is directed at the matte through unimmersed water-cooled nozzles. Fresh matte enters continuously at the front part of the furnace, where the nozzles are located, while slag overflows at the rear. The process is thought to be applicable to copper, copper-nickel and nickel mattes, but requires further study.

The flow of heat and the distribution of temperature around a copper converter tuyère have been examined by Krivsky and Schuhmann,[9] who emphasise the pronounced cooling effect of the tuyère itself on the problem of tuyère accretions and tuyère punching. Clark and McDowell[10] confirm that both burnt chrome-magnesite and burnt magnesite brick give excellent service in copper converters, but note certain differences in the behaviour of the two materials. In particular, sulphides were found to penetrate much more deeply into the magnesite than into the chrome-magnesite refractory.

Refining

Horváth[11] has compared the variations in composition of blister copper during the oxidising stage of fire refin-

ing in a rotary furnace with those deduced theoretically from thermodynamical principles. Although agreement between theory and experience was not always exact, it was sufficiently so to suggest that thermodynamical considerations should be helpful in rationalising the fire refining process.

Evidence put forward by workers in Sweden[12] indicates that costs of electrolytic copper refining can be reduced by adopting higher current densities than those normally employed. Their publication describes experiments at current densities up to nearly 47 A./sq. ft. (500 A./sq. m.) in specially constructed channel cells.

The production of rolled sheet from electrodeposited cathode copper has been patented in Japan.[13] The copper is plated onto stainless steel from an acid sulphate solution, with thiourea and glue as additives. After stripping from the steel, it is several times cold rolled and annealed, either in a vacuum or in a non-oxidising atmosphere, to give pure copper sheet containing no more than about 0·0015% of oxygen. Though there is nothing revolutionary in the idea, such a process does not appear to have been exploited commercially heretofore.

Foundry Practice

Gating and Moulds

Though much work has already been published on the running and gating of copper-alloy castings, a contribution to this subject by Glick, Jackson and Ruddle[14] has differentiated between alloys such as phosphor-bronze and the gun-metals, which do not form harmful dross, and those like aluminium-bronze in which the presence of oxide skins can create difficulties. The authors make practical recommendations for running and gating both types, and also compare the flow of molten copper alloys through channels in green-sand and shell moulds, giving the dimensions of tapered sprues required for a particular rate of flow. More academic in character were experiments by Adams and Taylor[15] on the flow of heat from sand castings. They claim to have developed a satisfactory technique for measuring the thermal behaviour of sand moulds under casting conditions.

Wright[16] makes a plea for the adoption of copper moulds, either solid or water cooled, for the production of ingots, billets and so forth for subsequent fabrication. He maintains that the much higher thermal conductivity and diffusivity of copper moulds outweigh their increased cost over moulds of cast iron. In the case of copper-faced water-cooled moulds, he resurrects the idea of adding a little chromium, cadmium or silver to the copper in order to reduce vulnerability to mechanical damage.

Properties of Foundry Alloys

In a contribution to the International Foundry Congress held in Belgium last year, Hudson, Wood and Gregg[17] describe experiments to determine the influence of section thickness on the mechanical properties of several gun-metals. They demonstrate that composition has an important bearing in the sensitivity of such alloys to section thickness, and conclude that, in the case of leaded gun-metals, sensitivity is markedly reduced by the addition of a small quantity of nickel. Somewhat similar is the work of Flinn and Meilke[18] on the influence of thermal gradients during solidification on the pressure-tightness of 85 : 5 : 5 : 5 leaded gun-metal. Their data indicate that pressure-tight castings of 2 in. square bar sections were obtained when the thermal gradient exceeded 33° C. (60° F.)/in. along the length. This gradient could be achieved by the judicious location of tapered chills.

While ships' propellers cast in aluminium-bronze containing iron and nickel (B.S. 1400-AB2-C) are well established in this country, they appear to be something of a novelty in America to judge from a publication by Smith,[19] who discusses foundry problems encountered with this "new marine propeller alloy." Among other expedients he advises gas flushing during melting and the use of water-cooled chills to promote directional solidification. Brunhuber[20] has studied the heat treatment of aluminium-bronze castings, including those containing nickel, and recommends optimum heat treatment cycles.

Akin to both the preceding paragraphs, French[21] singles out the adjustment of cast gun-metal compositions to ensure pressure-tightness, and the development of copper-manganese-aluminium alloys for propellers and general engineering castings, as major post-war advances in the copper-base foundry field.

In order to minimise gas porosity in nickel-silver ingots for rolling to sheet, and with it most of the defects found in the product, Hegedüs and Stefán[22] recommend the following sequence of operations: (*a*) melt the manganese, amounting to 0·3% of the total weight of the charge; (*b*) melt the copper; (*c*) charge nickel-silver scrap; (*d*) add oxide-free nickel and any copper-nickel scrap; (*e*) when molten, stir and cover with dry charcoal; (*f*) add zinc; (*g*) add phosphorus. The authors maintain that this method of charging avoids contamination with nickel oxide, which would increase the gas content of the melt.

Copper in Cast Iron and Steel

Bleyenberghe and Coussement[23] cite factual evidence of the benefits to be gained by adding copper to ferrous foundry products. For example, 3% of copper improved the quality of grey iron castings, and when such material was shell moulded 1·5% of copper effectively enhanced resistance to wear. The same was true of chrome-manganese steel with 2% of copper, while the incorporation of 1·5% of copper in cast carbon steels increased the fluidity of the metal and so diminished rejects. A contribution by de Sy[24] is in much the same vein: he maintains that copper additions to grey iron prevent thin sections from chilling and the formation of free ferrite in heavy sections. The result is a uniform structure of good strength and hardness but with no hard or soft spots to impair machinability. Like Bleyenberghe and Coussement, de Sy also states that the addition of copper improves the resistance of grey iron to wear. He adds that copper is a relatively inexpensive addition.

A recent patent[25] covers a three-stage heat treatment process, leading to graphitisation, for cast irons containing between 0·7 and 3% of copper.

Miscellaneous Foundry Techniques

Cooksey, Kondic and Wilcock[26] have developed a new type of mould for assessing the fluidity of foundry alloys, and have used it to determine the influence of aluminium additions on the fluidity of 60 : 40 brass. They report that fluidity remained almost unchanged with aluminium contents up to 0·1%, and then diminished owing to the formation of surface films of aluminium oxide on the molten metal.

Garlick and Wallace[27] have demonstrated that grain refinement can be achieved by applying vibrations during the solidification of various metals and alloys, including brass. They found that the degree of grain refinement caused by vibration tended to increase with the solidification contraction of the metal, and conclude that the waves of alternate high and low pressure set up by vibration increase the nucleation rate of the solidifying phases.

In the course of some work on spheroidal graphite cast iron, Ramamurthy[28] has observed that magnesium nitride is an effective addition for desulphurising and degassing copper-base alloys.

Metalworking Techniques

Rolling and Wiredrawing

Nielsen[29] considers in detail the metallurgical factors affecting the production of copper sheet, paying particular attention to the qualities of the various forms of cast slabs available commercially, with emphasis on modern continuously and semi-continuously cast products. A graphical aid to the minimisation of scrap formed during the cold rolling of copper and copper alloys has been published by Emicke.[30]

Two items concerning the production of coated copper wire may be mentioned. The process developed by the Westinghouse Electric International Company for the production of aluminium-coated copper wire with an intermediate layer of silver has been patented in this country,[31] and a method of drawing very fine copper wire with an insulation of glass directly from the molten metal has been proposed in the U.S.S.R.[32]

Hot Working Processes

Hirst and Ursell[33] have attempted to rationalise the factors which limit extrusion ratios. They emphasise the value of a graph of extrusion ratio against billet temperature, covering different press capacities, ram speeds and coefficients of friction, and explain how several families of curves superimposed on such a graph can be used to predict limitations imposed by preheat temperature and temperature rise during extrusion. Cudahar[34] has examined the extrusion over a range of temperatures of copper and several α-brasses containing 1% of chromium. He reports that the tensile strength of the extruded rods was approximately 15% above that of similar chromium-free materials, and that the elongation values remained high.

For an aluminium-bronze containing 8–10% of aluminium, with 1·5–2·5% of manganese and restricted fractional percentages of other elements, including iron and nickel, Popova and Kravchenko[35] recommend a forging temperature between 900° and 800° C. To relieve internal stress after forging they advise placing the work in a furnace at 200° C., heating to 380° C. at the rate of 80° C./hr., holding at 380° C. for four hours, cooling to 200° C. at 20° C./hr. and then cooling in air. There would seem to be some possibility of breakdown of β into $\alpha + \gamma_2$ during this rather prolonged period at 380° C.

Cold Forming Processes

While the idea of using edge-annealed or edge-heated blanks for deep drawing is not particularly novel, it does not appear to have achieved much popularity in the copper and brass industry in this country. From Soviet sources comes a report[36] of experimental work on copper and brass, among other metals, with a press specially designed to provide preheating of the blank flanges and simultaneous cooling of the walls of the drawn cup. Distinct advantages are claimed for the process. Scheven[37] has critically compared the performance of various types of presses and drop hammers for the production of cutlery and flat-ware from brass, nickel-silver and stainless steel, while Keller[38] compares aluminium-bronze dies with those of steel for deep drawing stainless steel sheets. He makes the point that, owing to their excellent antifriction properties, less expensive lubricants are needed for the aluminium-bronze dies.

Dynamic and explosive techniques of metal forming are currently evoking considerable interest. Ottestad[39] predicts important developments in this field during the next decade, and cites copper extrusions with 0·01 in. fins and precision gears forged in one blow as examples already achieved with non-ferrous metals. Feddersen[40] gives information on the development of this type of process, with applications to particular components in copper, among other metals, while the use of water to transmit the explosive force has also been described.[41] Among materials successfully tested in this way was copper, in thicknesses from 0·0015 to 0·5 in.

Plating and Finishing

Literature on the finishing, including electrolysis, of copper and copper alloys is invariably voluminous, but is generally somewhat ephemeral in character. There are numerous reviews of current practice, which contribute little that is fresh; new plating methods are constantly being developed and patented, but in most cases they are little more than variants of established techniques, often claiming advantages of special additives for brightening or similar purposes. To deal with so large a mass of information in detail would overload this survey, and attention is therefore confined to a few items which seem to be of particular interest and value.

The Electrodeposition of Copper

The action of thiourea as an addition to acid sulphate plating baths has been examined by Ke,[42] who reports that it gave rise to a uniform bright polycrystalline deposit over the entire surface of a single-crystal sphere of copper. Clearly, thiourea is a strong inhibitor of epitaxy. In contrast, Skewes[43] has shown that the presence of hexavalent molybdenum in the acid copper sulphate bath causes coarsely-crystalline and brittle deposits, attributable to a decrease in the cathode overpotential. As a stop-off for carburising of steel parts, Marchenko[44] recommends an ammoniacal solution of copper and nickel sulphates, together with ammonium and sodium sulphates, operated at room temperature with anodic and cathodic current densities between 2 and 3 A./sq. dm.

When electroforming copper parts of complex shape, it has been suggested[45] that aluminium, which can be dissolved out in a 40–50 oz./gal. caustic soda solution at 60° C., makes an excellent former. Duncan[46] gives some observations on a process called "electrolytic casting," akin to electroforming, by means of which thick-walled heavy products up to 2 tons in weight and 3 in. wall thickness can be produced in copper, among other materials. Full details are not yet available, but it is stated that dimensional tolerances of ± 0·005 in.

can be achieved. It remains to be seen whether the claims are substantiated.

Electrodeposition of Copper Alloys

Sree and Rama Char[47] describe conditions under which zinc can be co-deposited with copper from pyrophosphate baths to form coatings containing from 60 to 100% of copper, with homogeneous α-solid solution structures. They claim that the method has some advantages over the more orthodox cyanide bath for brass plating. Somewhat similar in scope is the work of Priscott[48] on the electrodeposition of copper nickel alloys from solutions containing copper and nickel sulphates together with trisodium citrate. Preliminary tests have indicated that the solution is capable of giving very uniform metal distribution, and that the composition of the deposit can be controlled over a wide range.

Ramanathan[49] has determined the diamond pyramid hardness of a series of electrodeposited copper-tin alloys, including speculum, and reports values up to 520 ± 9HV. On the evidence of the hardness tests, the deposits were found to be compact, homogeneous and isotropic.

Electroplating on Copper Alloys

Two interesting notes have appeared on the electroplating of leaded brasses and bronzes. One of these[50] refers to chemical drop tests to assess the quality of the basis metal prior to bright nickel plating, and recommends the application of a relatively thick copper coating, which should be polished, beneath the nickel. The other[51] states that, in preparation for silver plating, it is sometimes advantageous to dip leaded-brass, after cleaning, into a dilute solute of hydrofluoric acid at room temperature.

It is worthy of note that a court in Wuppertal, Germany, has ruled that silver-plated tableware cannot be advertised in that country as "first quality" if the basis metal is brass instead of nickel-silver.[52]

Reddy and Wilman[53] have investigated by electron diffraction the structure and growth of iron and chromium electrodeposits on smooth electropolished copper, and on single crystal facets, while Grau[54] records some practical experiences in the hard chromium plating of copper and brass, among other metals, by the Zero-Mist process. His results indicate that the coatings on the copper-base alloys, with the exception of cast brass, had no imperfections, though pits and nodules were encountered with certain other basic materials.

Non-Electrolytic Coating Processes

Conditions and procedures for the vacuum deposition of various metals, including copper, are given by Remond and Johnson,[55] who state that copper alloys can also be deposited in this way; they specifically mention aluminium-bronze. Schultze[56] records that copper wires up to 1,000 ft. in length have been coated with molybdenum by this technique, the coatings being sufficiently ductile to permit spooling the wire.

By the thermal decomposition of nickel carbonyl, coatings of nickel can be deposited on most metallic surfaces, Owen[57,58] gives details of the method, and states that adherence of the nickel to copper is exceptionally good, even without subsequent heat treatment. Fishlock[59] observes that the versatile electrophoretic coating process is generally faster than electroplating, and cites as typical examples the deposition of stainless iron-nickel-chromium alloys and antifriction coatings of molybdenum disulphide on copper.

Samuels,[60] an acknowledged expert on metallographic polishing techniques, has turned to a consideration of industrial polishing, and has shown that such processes are generally effected by cutting rather than by surface flow. His publication includes quantitative data on the deformed surface layer of brass specimens finished by a representative range of industrial methods.

Jacquet,[61] the originator of electropolishing, describes an application of the method which employs a hand-held electrode, water-cooled and covered by an absorbent sheath saturated with electrolyte. Applications which he mentions include the polishing of phosphor-bronze and cast brass. More academic is the publication of Lorking,[62] who discusses the mechanism of electropolishing copper in orthophosphoric acid solutions. He concludes that macro-polishing is basically dependent on the rate of diffusion of ions through a viscous anode film of thickness depending on the level of the surface irregularities, whereas polishing on a micro scale occurs when a film of oriented polar chains of molecules forms on the surface.

Painting and Enamelling

In preparing brass sheet for painting, Stein and Podmore[63] recommend a short immersion in an alkaline tin solution; alternatively a thin electrodeposit of tin or tin-zinc is satisfactory. For the application of vitreous enamel powders to copper for jewellery and decorative purposes, an air-acetylene torch is recommended.[64] Lower in temperature than the oxy-acetylene flame, this fuses the enamel in an easily controlled way, permitting the use of threads of enamel and swirling tools for the production of ornamental effects.

Staining by Perspiration

In metal-finishing industries, staining by perspiration from operatives' hands not infrequently creates a problem. A recent note[65] gives the chemical nature of sweat and cites various compounds which are available for its control. Special mention is made of aluminium chlorhydrate applied to the hands.

Technological Properties

Tensile Properties

The influence of rate of extension, within the range 2–470 mm./min. on the tensile strength and elongation of various materials, including copper and bronze, has been shown by Volkogon and Primatova[66] to be slight. This is in accordance with observations of earlier workers, and also with theoretical considerations which predict that the stress applied during the tensile test will remain in balance with the progressive yield stress of the metal irrespective of extension rate, provided that the rate remains constant and accelerations are excluded. Somewhat similar are the results of Balasse and Gaspard,[67] who show that tensile tests on copper wire give more consistent results if the load is increased progressively than if it is applied intermittently. Thomas and Averbach[68] have examined the early stages of plastic deformation in copper of exceptionally high purity, and conclude that the minute initial extensions are dependent on the third power of the grain size.

Internal oxidation at 900°–1,000° C. of copper containing fractional percentages of aluminium, magnesium, chromium or beryllium has been shown by Ali and Phil-

lips[69] to increase the yield strength, particularly at low temperatures. The strengthening effects of internal oxidation persisted throughout the stress-strain curve, but since a marked loss of ductility occured at all temperatures between 196° C. and 500° C., only moderate improvements in tensile strength were, in fact, realised.

Goldspiel[70] has studied the influence of iron, manganese and silicon on the properties of cast 90 : 10 and 70 : 30 cupro-nickels. He advises somewhat different percentages of these elements to secure optimum mechanical properties and optimum welding behaviour, respectively.

Fatigue Behaviour

Experiments by Wadsworth and Hutchins[71] have demonstrated that the fatigue life of copper and aluminium is many times greater in a vacuum than in air, whereas that of gold remains unaffected. The presence of air does not influence the stage at which the first minute cracks develop, but greatly accelerates their rate of propagation in the case of the more oxidisable metals, copper and aluminium. Measurements by Frost[72] of the rate of growth of fatigue cracks in copper and other metals under alternating tensile stress indicate that the rate of propagation is approximately proportional to the current crack length. Using ultrasonic and magnetostrictive devices to induce fatigue in oxygen-free high-conductivity copper, among other metals, Mason[73] has developed a relationship between internal friction and fatigue failure. In contrast, Dugdale[74] has determined the fatigue behaviour of copper under cycles of large amplitude.

Aluminium-Bronzes

Extending their range of high-manganese aluminium-bronzes, J. Stone and Co., Ltd.,[75] have patented a cold-workable type which is claimed to be resistant to corrosion and to creep at temperatures up to 400° C. An investigation of the mechanical properties and heat treatment of a somewhat similar alloy has been published in Italy.[76]

A patent[77] covering a complex aluminium-bronze of exceptionally high aluminium content for the manufacture of press tools has appeared. It contains about 5% each of iron and manganese, about 2% of nickel or chromium, and between 12 and 24% of aluminium. Another patent, by Klement of Ampco Metal Inc.,[78] claims that the resistance to stress corrosion cracking of α-aluminium-bronzes in steam atmospheres can be improved by the addition of a little tin or silver, or both.

Chromium Copper

Doi [79] has determined the activation energy for the precipitation process in chromium-copper. He reports that small additions of silicon tended to decrease the tensile strength, and also todiminish the ageing rate, though precipitation became more difficult to control. He therefore regards more than 0·08% of silicon as objectionable in chromium-copper. On the other hand, iron had little influence on precipitation hardening.

A broad investigation of the creep and other elevated temperature properties of chromium-copper, with and without additions of nickel, has been carried out by Simakovsky.[80] Time-to-rupture tests suggested that the life of chromium-copper at from 280° to 350° C. is approximately three times that of ordinary copper, though there was a marked decrease in ductility. Weight-loss tests in steam showed that the material was not inferior to copper, while the addition of about 5·7% of nickel appeared to be generally beneficial.

A British patent[81] claims that the addition of 0·05–0·5% of titanium improves the tensile strength and hardness of heat treated chromium-copper, with little loss in electrical conductivity.

Alloys Containing Titanium

Other copper alloys containing relatively small quantities of titanium have also received attention. Saarivirta and Cannon[82] have developed a straight copper-titanium alloy, carrying 4·3% of titanium, for electrical applications. In the cold-worked and precipitation-hardened condition, the tensile strength is said to exceed 90 tons/sq. in. Kalinin and Spiridonova[83] report that additions of up to 4% of nickel or 1% of cobalt conferred no benefit on the hardness, tensile strength or elongation of copper-titanium alloys. On the other hand, Biswas and Gupta[84] found that additions of titanium to 70 : 30 brass improved the resistance to corrosion and to oxidation at temperatures up to 350° C., provided that the solid solubility limit was not exceeded. Hardness and tensile strength were also improved, within the same limitation, and grain growth was markedly inhibited.

Embrittlement in Naval Brass

A type of embrittlement in naval brass, hot or cold rolled with interstage annealing, has been attributed by Finegan[85] to precipitation of the δ-phase while cooling. He advocates careful adjustment and control of the copper-tin-zinc ratio within the limits of the specifications for naval brass.

Copper Steels

According to Rickett and Leslie,[86] copper greatly retards recrystallization in low carbon steel, and tends to increase its hardness after annealing. Comparatively coarse, elongated ferrite grains can, however, be obtained by careful control of the heat treatment, and the hardening effect of copper is thereby minimised. An extensive series of tests by Bush and Lindsay[87] on rolled and annealed copper-bearing low carbon steels has established the strain hardening behaviour of such materials. Unhappily the authors used the misleading power function to express their strain hardening data, but the results, critically analysed, show convincingly that copper does not impair the cold-forming properties, except in so far as slightly increased stresses are required to deform the metal. The essential ductility, namely that up to the maximum load point, remains sensibly constant as the copper content is increased to 0·48%, the highest tested.

to be continued—

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BISRA Change

Miss I. M. Slade, BISRA's information officer for many years, has relinquished that post to take on consulting duties in the Association's operational research department at the Battersea Laboratories. She will be closely concerned with ergonomic studies, especially in connection with problems involving safety and protective clothing, a field in which she has for long been an authority. Mr. L. W. Stevens-Wilson, formerly head of the development and steel user section, has accordingly taken over new responsibilities. The distribution of information, the handling of inquiries, and the development and exploitation of the results of research, all of which are related, have been combined into a single unit. This will be called Development and Information Services, with Mr. Stevens-Wilson as head.

Distribution of Electrode Consumption in an Electric Arc Furnace

By J. Ravenscroft, B.Sc., A.M.I.E.E., A.R.T.C.S., and M. Preston,* Assoc.Met., A.I.M.

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Measurements of the losses at the sides and the bottoms of 4 in. diameter graphite electrodes used in the B.I.S.R.A. 10 cwt. experimental arc furnace indicate that during the melting period: (1) rate of electrode loss increases with electrode current; (2) for a given furnace voltage, rate of loss increases with power input; (3) for a given power input, rate of loss decreases with increase of furnace voltage; and (4) total electrode consumption decreases with increase of furnace voltage. The increase of the rate of electrode loss with increasing current is mainly due to increased bottom loss. Rates of loss during the subsequent steelmaking process have also been measured.

WHEN the costs of converting steel scrap into ingots by the electric process are examined, the largest two items are found to be the costs of electricity and electrodes. The latter accounts for approximately 15% of the total conversion costs. Some of the factors governing the consumption of graphite electrodes in the arc furnace have been studied and reported elsewhere.[1-4] The object of this present investigation has been to determine the effects of furnace voltage, electrode current and power input on electrode consumption, and especially on the distribution of electrode wear.

The work was carried out on the B.I.S.R.A. 10 cwt. experimental arc furnace, which has been fully described previously.[5] The roof was set at its highest level, 2ft. 2 in. above the sill, and 4 in. diameter graphite electrodes were used on a 12 in. pitch circle diameter. The resistivity of the electrodes was measured and only those within the range 900–1,200 $\mu\Omega$ cm. were used.

Experimental Programme

The steelmaking operation can be divided into two stages, melting and refining. The aim with all furnaces is to keep the melting time down to a minimum, whereas the duration of the refining period depends largely on the chemistry of the process. For this reason the major part of the investigations were made during the melting stage, although some results were obtained during the refining period.

Since it was not possible to determine with accuracy the exact point at which melting was completed, the period studied was that from power-on until the bath reached a temperature of about 1,600° C., because there would then be no risk of unmelted scrap remaining on the furnace bottom. Temperatures were taken with platinum/platinum-rhodium thermocouples.

Range of Variables used and Measurements made

The independent variables were furnace voltage, power input and electrode current; the dependent variable being electrode consumption.

Furnace Voltage

For the determination of electrode consumption during melting, only two furnace voltage tappings were used, namely, the No. 4 and No. 8 taps, which give open circuit voltages of 104 and 180 V., respectively. The electrode consumptions for a range of power inputs and currents on the No. 4 tap were compared with those on the No. 8 tap. The procedure during melting was to set the furnace voltage at the desired level at the commencement of the heat, the furnace being operated on this voltage until melting was completed, that is, when the bath temperature reached 1,600° C.

The refining period can be sub-divided into the oxidising and reducing stages, and for a study of electrode consumption three voltage settings—88, 110 and 130 V.—were used during these periods, and the results compared on each tap.

Power Input and Electrode Current

For a given furnace voltage, the power input increases as the electrode current is increased. A series of experiments was made during melting with the electrode regulator system set to control the three electrode currents at the desired level at a fixed furnace voltage. The electrode current was kept constant throughout the melting period. The range of currents used on the No. 4 voltage tap was 1,450–3,450 A., and the current range on the No. 8 tap was 1,000–2,250 A., the corresponding power inputs being 240–460 kW. and 260–490 kW., respectively.

A steady power input is not obtained during melting owing to constant variations in the lengths of the arcs as the scrap melts. Therefore, for comparing the results, the mean power input over the melting period was taken from the chart of the furnace recording kilowattmeter, and the corresponding mean electrode current was obtained from the triplex recording ammeter.

It was not possible to cover the same current range on each voltage tap, because (*a*) it is not practicable to melt down on the 104 V. tap at a current less than 1,400 A., and (*b*) it is not possible to exceed a current of 2,300 A. on the 180 V. tap without grossly overloading the 500 kVA. furnace transformer.

For the experiments made during the refining period, the current was varied as necessary to give the required heat input to the charge, which is governed by the required metallurgical reactions within the furnace. The average oxidising period was 1¼ hr., and the average reducing period was 1½ hr.

* Mr. Preston is now with the Cromite Foundry Co., Ltd., Frome, Somerset.

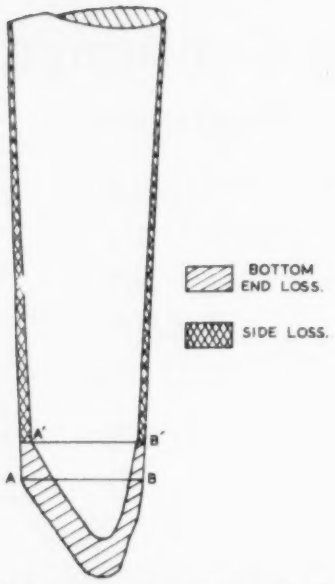

Fig. 1.—Typical cross-sections of electrode before and after test, showing distribution of electrode wear.

Electrode Consumption

To separate the electrode losses during melting, oxidising and reducing, alternative sets of electrodes were used. Each electrode was weighed before being put on the furnace, and when the period under study was completed the set of electrodes was quickly removed from the furnace and replaced by a second set, the first set being allowed to cool down before re-weighing.

Electrode consumption occurs in two ways :—

(*a*) by wear at the bottom end or tip of the electrode, and

(*b*) loss by oxidation over the whole surface area of the electrode within the furnace.

Arc furnace electrodes almost invariably wear unevenly at the tip, electro-magnetic interaction between the three arcs producing an inclined flat surface at the tip of the electrode, since the arcs tend to strike at the outer edge of the pitch circle diameter. The upper edge of this inclined surface is marked as point A in Fig. 1, which illustrates typical cross-sections of an electrode before and after test in the furnace. For the purpose of separating the loss at the end from loss at the sides of the electrode, the tip of the electrode is defined as all of the electrode below the plane AB in which point A lies. After a test, A is displaced to A' and the new tip is the volume of the electrode below the plane $A'B'$.

End loss was determined by measuring the volume of the tip by displacement (Fig. 2) before and after each test, the difference between the two volumes giving the loss as indicated in Fig. 1. For calculating the weight of electrode consumed, a figure of 1·57 was taken for the bulk density of graphite. Errors due to the possible absorption of the liquid by the graphite were avoided by immersing the electrode prior to making the initial measurement. Electrodes were weighed before and after each experiment to obtain the total electrode consumption, and the weight lost from the sides was obtained by subtracting the end loss from the total loss in weight. It was assumed that side loss below the moving plane $A'B'$ was negligible.

A number of electrodes were taken out of the furnace as quickly as possible and weighed immediately, and then weighed again when cold. It was found that an average loss of 2 oz. occurred from each electrode during cooling down. Assuming that all this loss occurs due to oxidation at the sides of the electrode, 6 oz. was subtracted from the total loss of each set of electrodes when the electrodes were finally weighed cold.

Tabulation of Results

The results for electrode consumption during melting are presented in Table I, and the results for the refining period are given in Table II. The figures for furnace power are the power input to the furnace as measured at the electrode clamps. The distribution of electrode wear between the sides and the tip is given and rates of electrode loss in lb./hr. have also been calculated for each period.

As an indication of the cost of graphite consumed during melting, electrode wear is related to charged weight of steel scrap and expressed in the usual notation of lb. wt. of graphite consumed per ton of steel.

The Effects of the Independent Variables on Electrode Consumption

(*a*) *Melting.*—The effects of furnace voltage, power and electrode current on rate of electrode consumption are illustrated by Figs. 3–8. Total lb./hr. for 27 casts, 13 on No. 4 voltage tap and 14 on the No. 8 tap, are plotted against mean electrode current in Fig. 3 and against power input in Fig. 4. There is a strong correlation between rate of electrode consumption and electrode current, electrode consumption increasing with current, the calculated coefficient of correlation ($r = 0{\cdot}833$) being very high, and for the number of observations concerned is, statistically, very significant. The plot of lb./hr.

Fig. 2.—Determination, by a displacement method, of wear at the bottom end of a 4 in. diameter electrode.

TABLE I.—DISTRIBUTION OF ELECTRODE WEAR DURING MELTING

Furnace Voltage	Cast No.	Charged Weight (cwt.)	Mean Electrode Current (A.)	Power Input (kW.)	Melting Time (hr.-min.)	Total Electrode Loss (lb.)	End Loss (lb.)	Side Loss (lb.)	End Loss (%)	Total Rate of Electrode Loss (lb./hr.)	Rate of End Loss (lb./hr.)	Rate of Side Loss (lb./hr.)	Total Electrode Loss (lb./ton of charge weight)	End Loss (lb./ton of charge weight)	Side Loss (lb./ton of charge weight)
No. 4 Voltage Tapping (104 V. on open circuit)	A.533	10	1450	240	2 13	4·69	—	—	—	2·12	—	—	9·38	—	—
	A.623	10	1650	260	1 28	4·25	2·10	2·15	49	2·99	1·43	1·47	8·50	4·20	4·30
	A.564	11	1700	270	1 53	4·81	2·15	2·66	45	2·56	1·14	1·42	8·75	3·91	4·84
	A.585	11	2000	300	1 30	3·56	2·16	1·40	61	2·37	1·44	0·93	6·48	3·93	2·55
	A.563	11	2050	315	1 48	5·625	2·97	2·655	53	3·12	1·65	1·47	10·23	5·40	4·83
	A.558	10	2250	365	1 15	3·875	2·50	1·375	65	3·10	2·00	1·10	7·75	5·00	2·75
	A.979	10	2350	380	1 18	4·75	2·21	2·54	47	3·65	1·70	1·95	9·50	4·42	5·08
	A.624	10	2450	365	1 8	4·97	2·27	2·70	46	4·39	2·00	2·39	9·94	4·54	5·40
	A.988	10	2725	410	1 7	5·875	2·71	3·165	46	5·26	2·43	2·83	11·75	5·42	6·33
	A.987	10	2750	440	1 3	5·625	2·38	3·245	42	5·36	2·26	3·10	11·25	4·76	6·49
	A.535	10	2800	440	1 0	4·06	—	—	—	4·06	—	—	8·12	—	—
	A.556	10	2900	460	1 12	4·75	3·44	1·31	72	3·96	2·87	1·09	9·50	6·88	2·62
	A.629	10	3450	460	0 48	3·625	2·74	0·885	76	4·53	3·42	1·11	7·25	5·48	1·77
No. 8 Voltage Tapping (180 V. on open circuit)	A.553	11·5	1000	280	2 27	5·625	0·80	2·825	22	1·48	0·33	1·15	6·30	1·39	4·91
	A.550	10	1000	270	1 54	2·625	0·58	2·045	22	1·38	0·31	1·07	5·25	1·16	4·09
	A.980	10	1200	300	1 50	4·56	0·73	3·83	16	2·48	0·40	2·08	9·12	1·46	7·66
	A.565	11	1200	330	1 42	3·56	1·02	2·54	29	2·09	0·60	1·49	6·48	1·85	4·63
	A.561	10	1250	310	2 2	4·81	1·20	3·61	25	2·37	0·59	1·78	9·62	2·40	7·22
	A.986	10	1330	320	1 24	4·06	0·77	3·29	19	2·90	0·55	2·35	8·12	1·54	6·58
	A.546	10	1500	410	1 21	2·875	0·89	1·985	31	2·13	0·66	1·47	5·75	1·78	3·97
	A.562	11	1700	390	1 17	2·75	1·07	1·68	39	2·14	0·835	1·305	5·00	1·95	3·05
	A.642	11·5	1900	390	1 6	3·81	1·01	2·80	27	3·46	0·92	2·54	6·63	1·76	4·87
	A.551	11·5	2000	455	1 12	3·28	0·99	2·29	30	2·73	0·825	1·905	5·70	1·72	3·98
	A.978	10	2000	470	1 0	3·00	1·02	1·98	34	3·00	1·02	1·98	6·00	2·04	3·96
	A.965	10	2200	455	0 48	4·31	1·70	2·61	39	5·39	2·125	3·265	8·62	3·40	5·22
	A.973	10	2250	460	0 53	3·41	1·38	2·03	40	3·86	1·56	2·30	6·82	2·76	4·06
	A.981	10	2250	490	0 58	3·44	1·55	1·89	45	3·56	1·60	1·96	6·88	3·10	3·78

against power (Fig. 4) appears to have a large amount of scatter, but a closer examination reveals that there are two distinct trends, corresponding to the two furnace voltages, electrode wear increasing with power input. Treating the observations on each voltage tap as two distinct populations, there is in fact a good correlation between the two variables, the correlation coefficients being $r = 0{\cdot}832$ for the 104 V. tap and $r = 0{\cdot}693$ for the 180 V. tap. For the number of observations the result is very significant on the No. 4 voltage tap and significant on the No. 8 tap.

When the rate of electrode loss is separated into end loss and loss at the sides of the electrode, it is clear that there are very strong relationships between rate of end loss and electrode current and power input, Figs. 5 and 6, whereas there is considerable scatter in the plots of side loss against current and power, Figs. 7 and 8. There is, however, a slight trend for side loss to increase with current on the high voltage tap.

The correlation between end loss lb./hr. and electrode current is extremely high ($r = 0{\cdot}952$) and very significant, in fact, sufficiently significant for the number of observations and current range covered as to be nearly independent of any other factor.

A close examination of Fig. 6 suggests that increasing functions of the form indicated represent the data to a better degree than a straight line relationship of the form $y = mx + c$. If we accept the linear relationship for end loss against current (Fig. 5), then, from a consideration of typical arc furnace power characteristics,[6] the representation in Fig. 6 for end loss against power input is justified.

Total electrode consumption (lb. of graphite/ton of steel charged) is plotted against electrode current in Fig. 9 and power input in Fig. 10. There is considerable scatter in both these plots, and a linear relationship is not apparent. However, there is a definite trend for operation on the lower voltage to give a higher electrode consumption, the average on the 104 V. tap being 9·11 lb./ton as against 6·88 lb./ton on the 180 V. tap.

End loss lb./ton is plotted against current and power input in Figs. 11 and 12. Treating the observations on each voltage tap as two separate populations, end loss is found to increase with current and power input. There is a reasonable correlation between end loss and current on the No. 4 voltage tap ($r = 0{\cdot}665$) which is significant at the 5% level for the few observations taken, and there is a good correlation on the No. 8 tap ($r = 0{\cdot}748$) which

TABLE II.—DISTRIBUTION OF ELECTRODE WEAR DURING REFINING

Furnace Voltage	Cast No.	Total Rate of Electrode Loss (lb./hr.)	Rate of End Loss (lb./hr.)	Rate of Side Loss (lb./hr.)	End Loss (%)
(a) *Oxidising Stage*					
88 V. on Open Circuit	A.550	1·75	0·64	1·11	37
	A.561	2·22	0·48	1·75	21
	A.562	2·38	0·54	1·84	23
	Mean	2·12	0·55	1·57	27
110 V. on Open Circuit	A.546	2·27	0·40	1·87	18
	A.551	1·99	0·44	1·55	22
	A.553	2·94	0·75	2·19	27
	A.565	2·69	0·66	2·03	24
	Mean	2·47	0·56	1·91	23
120 V. on Open Circuit	A.563	2·19	0·48	1·71	22
	A.564	3·63	0·65	2·98	18
	Mean	2·91	0·57	2·34	20
All Oxidising Tests	Mean	2·45	0·56	1·89	23
(b) *Reducing Stage*					
88 V. on Open Circuit	A.550	1·32	0·90	0·42	68
	A.561	3·35	0·98	2·37	29
	A.562	2·16	0·92	1·24	42
	Mean	2·28	0·93	1·35	46
110 V. on Open Circuit	A.546	1·96	0·30	1·66	15
	A.551	2·90	0·76	2·14	26
	A.553	2·69	0·55	2·14	20
	A.565	2·24	0·76	1·48	34
	Mean	2·45	0·59	1·86	24
120 V. on Open Circuit	A.563	2·62	0·38	2·24	15
	A.564	2·15	0·67	1·48	31
	Mean	2·39	0·53	1·86	23
All Reducing Tests	Mean	2·58	0·69	1·69	29
All Refining	Mean	2·41	0·62	1·79	26

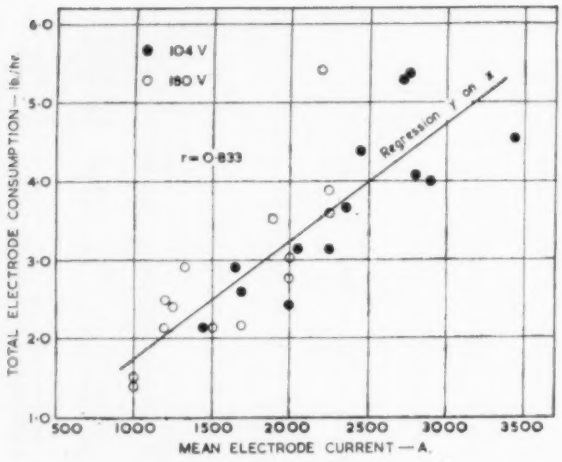

Fig. 3.—Total rate of electrode consumption v. current.

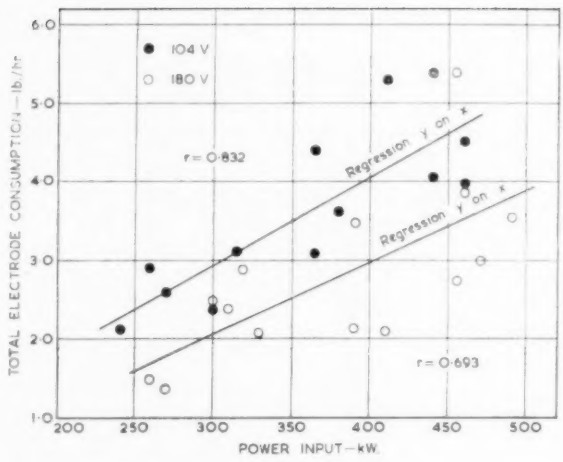

Fig. 4.—Total rate of electrode consumption v. power input.

is significant at the 1% level. The effect of voltage on electrode consumption is shown up more clearly in the plot of end loss lb./ton against power input (Fig. 12) and the correlations are quite strong ($r = 0{\cdot}719$ on the No. 4 tap and $r = 0{\cdot}693$ on the No. 8 tap) being significant at the 2% and 1% levels, respectively.

A summary of the statistical analyses made on Figs. 3–12 is given in Table III, where the equations for the regression lines of y upon x are also given.

An examination of the slopes of the regression lines proves to be of interest. From Table III we see that the slope of the regression line for Fig. 3 is 0·00148, that is, for an increase in current of 1,000 A. over the range 1,000–3,500 A., the predicted increase in the total rate of electrode wear would be 1·48 lb./hr. Similarly, from Fig. 5, the predicted increase in rate of end loss for an increase in current of 1,000 A. would be 1·26 lb./hr.

The slopes of the regression lines in Fig. 4 indicate that an increase in total rate of electrode loss of 1·12 lb./hr. and 0·91 lb./hr. could be predicted, on the No. 4 and No. 8 voltage taps, respectively, for an increase of 100 kW. in power input over the range 240–490 kW. The higher figure for the lower voltage can be explained by the fact that for any given change in power input on the No. 8 tap, a larger change in current is required on the No. 4 tap to produce the same change in power input.

The slopes of the regression lines in Fig. 11 for end loss against current for the low and high voltage taps, are 1·07 lb./ton per 1,000 A. and 1·06 lb./ton per 1,000 A., respectively, that is the regression lines are practically parallel.

In the case of end loss against power input, the slopes are 0·863 lb./ton per 100 kW. and 0·575 lb./ton per 100 kW., on the low and high voltage taps, respectively. The rather shallow slopes of these plots is explained by the fact that, as power input is increased, the rate of electrode loss increases, but the melting time decreases (Fig. 13), so that the two effects tend to cancel each other

TABLE III.—SUMMARY OF STATISTICAL ANALYSIS OF DATA SHOWN IN FIGS. 3–12

Graph Fig. No.	Co-ordinates	No. of Samples	Correlation Coefficient (r)	Regression Equation	Significance Level	Statistical Value of Correlation
3	x: Mean electrode current y: Total rate of electrode consumption	27	0·833	$y = 0{\cdot}00148x + 0{\cdot}274$	≤0·1	Highly Significant
4	x: Power input (104 V. tap) y: Total rate of electrode consumption	13	0·832	$y = 0{\cdot}0112x - 0{\cdot}412$	<0·1	Highly Significant
	x: Power input (180 V. tap) y: Total rate of electrode consumption	14	0·693	$y = 0{\cdot}00911x - 0{\cdot}672$	<1	Significant
5	x: Mean electrode current y: Rate of end loss	25	0·952	$y = 0{\cdot}00126x - 1{\cdot}085$	<0·1	Highly Significant
11	x: Mean electrode current (104 V. tap) y: Bottom end loss	11	0·665	$y = 0{\cdot}00107x + 2{\cdot}348$	<5	Trend
	x: Mean electrode current (180 V. tap) y: Bottom end loss	14	0·748	$y = 0{\cdot}00106x + 0{\cdot}297$	<1	Significant
12	x: Power input (104 V. tap) y: Bottom end loss	11	0·719	$y = 0{\cdot}00863x + 1{\cdot}744$	1·5	Significant
	x: Power input (180 V. tap) y: Bottom end loss	14	0·693	$y = 0{\cdot}00575x - 0{\cdot}159$	<1	Significant

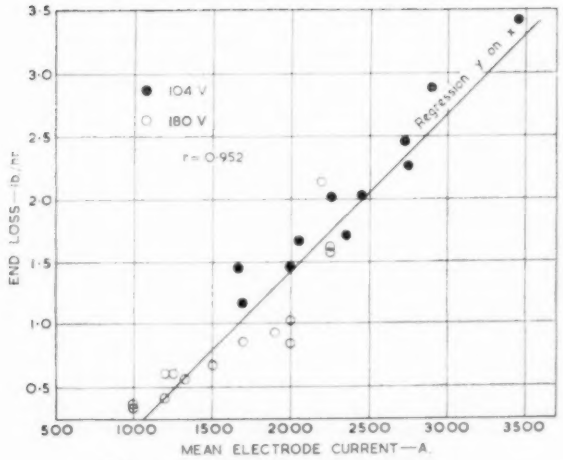

Fig. 5.—Rate of end loss v. current.

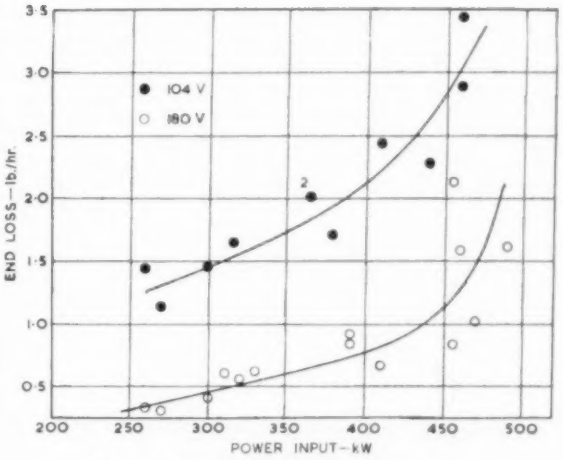

Fig. 6.—Rate of end loss v. power input.

out. Even so, the fact that for a given increase in power a larger increase in current is required on the lower voltage tap is clearly reflected in the slopes of the regression lines in Fig. 12.

Attempts to correlate side loss with power input and electrode current have not been successful, due to the influence of other variables. Factors which are known to affect side loss are as follows :—

(1) electrode taper—which influences the surface area of electrode exposed within the furnace ;

(2) graphite quality—as indicated by resistivity measurements ;

(3) age of the furnace refractories ;

(4) water cooling round the electrode ports—efficient sealing round the electrode ports is essential to stop excessive electrode erosion due to hot gases ; and

(5) air infiltration—which affects directly the rate of oxidation of the graphite.

Previous work[7,8] has shown that electrode wear is greatly influenced by the surface area of electrode exposed in the furnace, therefore, for all the work reported only electrodes which were naturally tapered due to normal use in the furnace were utilised. However, if it is assumed that side loss is directly proportional to surface area, then taking the two extremes for the possible shape of electrodes we have :—

(*a*) For a new 4 in. diameter cylindrical electrode

$$A = 4\pi l$$

where A is the surface area and l the length of electrode exposed in the furnace.

(*b*) For a conical electrode with a base diameter of 4 in. and a slant height S

$$A = 2\pi S$$

but the radius is small compared with S, so that $S \simeq l$, and, therefore

$$A = 2\pi l$$

Hence, taking the two extremes, a variation of 100% in side loss could only be expected due to electrode taper, whereas from Figs. 7 and 8 there is as much as 180% variation in side loss for the same power input on the No. 4 voltage tap.

An analysis made by Houseman[9] on the use of 10 in.

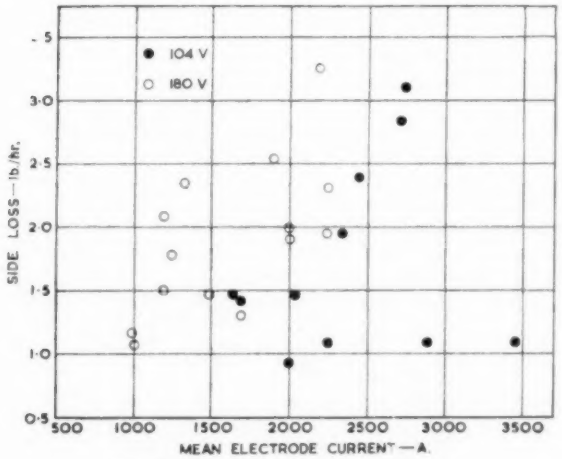

Fig 7.—Rate of side loss v. current.

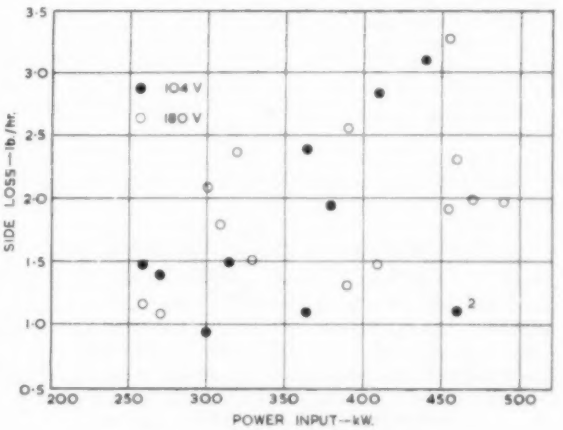

Fig. 8.—Rate of side loss v. power input.

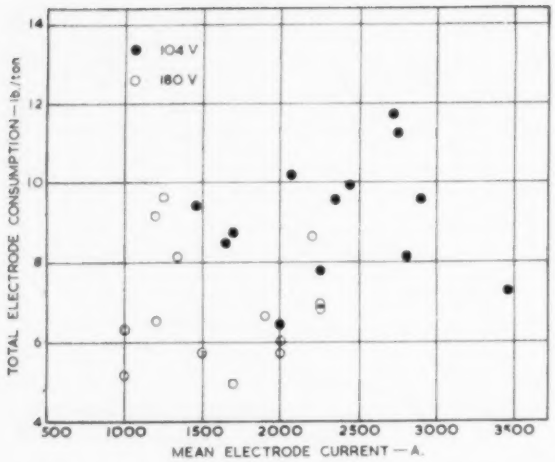

Fig. 9.—Total electrode consumption v. current.

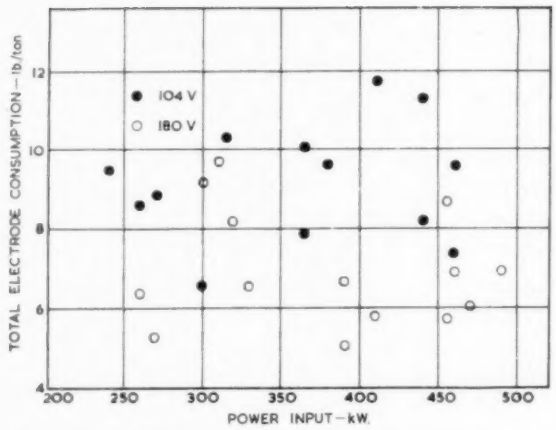

Fig. 10.—Total electrode consumption v. power input.

diameter graphite electrodes in two production furnaces has shown that there is a relationship between electrode consumption and electrical resistivity. As mentioned in the introduction to this paper, only electrodes within the resistivity range 900–1,200 $\mu\Omega$ cm. were used, which from the above analysis could only be expected to be responsible for a 20% variation in total electrode wear, whereas Fig. 10 shows variations in electrode consumption as high as 35–50% for the same power input at a given voltage.

No relationship could be found between side loss and life of furnace bottom, walls and roof throughout the series of experiments, although it is known that the age of the furnace refractories affects the heat losses from the furnace,[10] and hence melting time.

Care was taken throughout the trials to see that the electrode coolers and economisers were working efficiently and there should have been little variation in their performance over the period of the investigations. Similarly, care was taken to seal unnecessary furnace openings, and the door was only opened when necessary for the working of the charge.

(b) Refining

The results from nine tests on rate of electrode wear during the oxidising stage of the refining period are given in Table II*a*. The number of observations are too few to do a statistical analysis of the results, and there is a considerable scatter, but if the means for each voltage are considered, then there is the trend that as the voltage is increased the rate of electrode wear goes up, and this is primarily due to an increase in side loss with voltage. The percentage end loss at the tip of the electrode varies from 18–37%.

The results from the same casts during the reducing period are given in Table II*b*. Here again there is considerable scatter in the results, but, considering the means, there is a slight trend for increasing rate of wear with increasing voltage. In this case there is more variability in the figures for rate of end loss, which vary from 0·30–0·98 lb./hr.

The mean total rate of electrode wear during the oxidising and reducing stages is about the same, and for the eighteen results given in Table II is 2·41 lb./hr., the corresponding mean end loss and side loss being

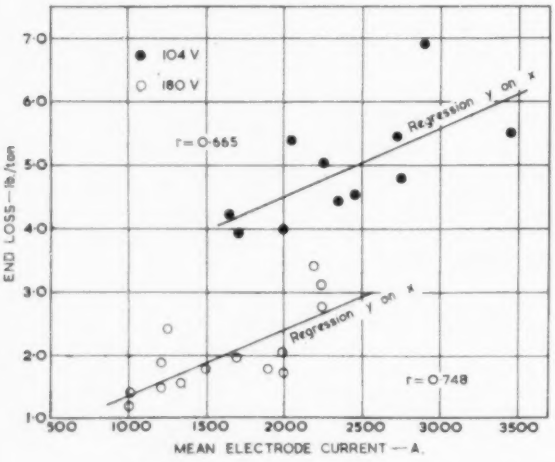

Fig. 11.—End loss v. current.

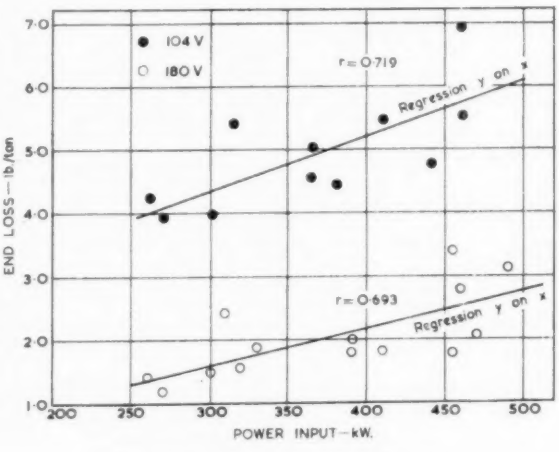

Fig. 12.—End loss v. power input.

0·62 lb./hr. and 1·79 lb./hr., respectively. The power required during refining is only about 100–150 kW. From Fig. 4 and Fig. 6, total rate of loss and end loss during melting for a power input of 200 kW. on the 104 V. tap would be about 1·8 lb./hr. and 1·0 lb./hr., respectively, so that side loss would be only about 0·8 lb./hr. Thus, although the rate of end loss is of the same order during refining and melting, the side loss, and hence the total rate of wear, is much higher during refining than melting, for the lower power inputs concerned. The rate of loss at the sides during refining represents about 74% of the total wear.

The possible explanation for the trend in the results during the two stages of the refining period is that during refining the electrodes are exposed to the full radiation from the hot furnace refractories and the molten bath and slag, and convection from the hot furnace gases, whereas during the melting period the sides of the electrodes are largely shielded by the scrap charge. This would account for rather high side losses at relatively low power inputs during refining. Recent experiments[11] have shown that as the voltage is increased during the refining period, the length of the arcs increases and with it the heat radiated to the furnace refractories. Thus, there will be a general increase in furnace temperature and more energy re-radiated to the electrodes.

During the reducing stage, at low voltage, the electrodes are often seen to be dipping in the slag which, of course, accelerates wear at the tip of the electrode. Evidence of this effect is indicated in the results for end loss for Cast Nos. A550, A561 and A562.

Conclusions

An analysis of the results obtained on the 10 cwt. experimental furnace shows that for the range of power inputs and electrode currents studied :—

(1) Total rate of electrode consumption during melting is closely related to electrode current in such a way that an increase in current is effective in producing an increase in electrode consumption. This is essentially due to the very close relationship between rate of wear at the bottom end of the electrode and electrode current.

(2) For a given furnace voltage, the total rate of electrode consumption during melting increases with increase of power input. For a given power input, the rate of electrode consumption decreases with increase of furnace voltage. The close relationship between rate of wear at the bottom end of the electrode and power input is largely responsible for these effects.

(3) Total electrode consumption during melting decreases with increase of furnace voltage.

(4) For a given furnace voltage during melting, the loss at the bottom end of the electrode increases with increase of current and power input. For a given current or power input, the end loss decreases as the voltage is increased.

(5) During the refining period there is the trend that total rate of electrode consumption increases with increase of furnace voltage. The increase in the rate of loss at the sides of the electrode with increasing voltage is largely responsible for this effect.

(6) The percentage of electrode wear at the sides is much higher during refining than during the melting period, and is probably due to the electrodes being exposed to greater radiation from the hot furnace refractories when refining.

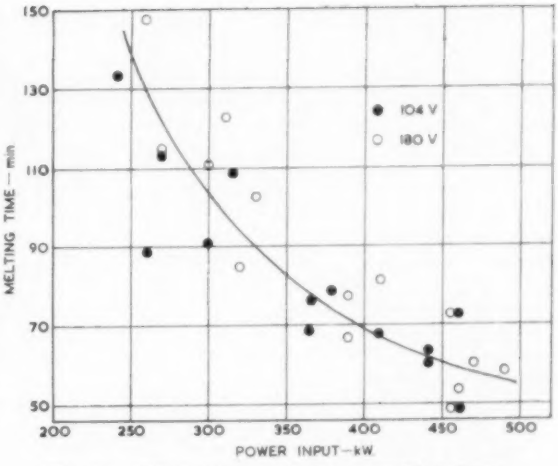

Fig. 13. Effect of power input on melting time.

Acknowledgment

The authors wish to acknowledge the guidance and co-operation of Mr. W. H. Glaisher in the earlier part of this work.

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New Copper Recovery System Sought

THE Anglo-American Group is carrying out research to find a suitable and economic process for recovering copper from the banded sandstone which overlies the main Nchanga orebody. Reporting this, Barclays Bank D.C.O., in a message from Northern Rhodesia, says that results are encouraging, and that if a successful method of extraction could be evolved large tonnages of low-grade ore could be drawn from current and old underground workings, as well as from the Nchanga open-pit, without any further major expenditure on development.

Rhodesian Fuel Tank Factory

THE new £100,000 factory opened in Salisbury, Southern Rhodesia, by Metal Containers Rhodesia, Ltd., to make large overhead fuel tanks for use on farms, is already turning out four times as many tanks per shift as the original estimate. Reporting this development, Barclays Bank D.C.O. Salisbury office adds that the factory is also manufacturing metal containers for dips, insecticides, kerosene and other farming requisites.

Significance of Weld Defects

AT a meeting of the Society of Non-Destructive Examination, held in London in December, Dr. R. Weck, Director of the British Welding Research Association, spoke on "The Significance of Defects in Welds." Dr. Weck began by emphasising that this was a most complex question to which he could not be expected to give any simple answer. The subject was incompletely understood and there was a need for much work of a fundamental nature and for much more data on service failures. The British Welding Research Association was active in both directions, but its present resources were rather inadequate for the task.

It was necessary to differentiate between defects in welds in construction subject only to static loading and those in construction subject to repeated or fatigue loading. The effect of a defect was two-fold. Depending on its size, it reduced the cross-sectional area producing a slight increase in the average or nominal stress. This effect could generally be entirely ignored under all loading conditions, unless the defect was very large in extent and produced a very considerable reduction in cross-sectional area. The second, much more important, effect of a defect was the production of concentrations of stress. Even this effect might be unimportant under static loading conditions, provided the material was in a sufficiently ductile condition to reduce the effect of stress concentrations caused by defects, by undergoing plastic deformation. When, however, a material was used below its transition temperature and if, in addition, residual welding stresses were present, defects played a very important role in the initiation of brittle fracture.

Under conditions of fatigue loading, however, the position was very different. The very high stress concentrations produced by defects might result in the production of premature fatigue cracks, with the possibility of early failure. However, even in this case, he did not believe that small, isolated pockets of porosity would have much effect, and he considered it was often a mistake to cut out such defects. Sharp corners might be introduced into the weld and be left in it after the "repair" had been completed. Such discontinuities had been shown to be capable of doing more damage than the defects which had been removed. Sometimes many of the worst defects were those in the surface which could be seen with the unaided eye. Small internal defects which could only be revealed by elaborate and costly methods of non-destructive testing were probably the least important.

Dr. Weck declared he was not unduly worried about the possibility of failures occurring in butt welds in pressure vessels, but he felt there was some cause for concern about failures occurring in welds joining stand pipes to pressure vessels. Such welds were harder to make and very difficult to inspect properly. Coupled with this, they were subject to much higher stress concentrations.

It was often considered desirable to heat treat welds to remove much of the residual stress. However, he was not sure that this was always really beneficial. There was recent evidence which appeared to suggest that if a defect were present at a place where there was a residual compressive stress, then the structure would be much safer in service if the compressive stress were not removed. In the case of a tensile stress associated with a defect, the evidence still pointed to the need to remove this stress. The general problem was, therefore, rather complex, and it would depend upon circumstances whether heat treatment was detrimental or beneficial.

Dr. Weck referred to a case where the weld contour had played a more important part in determining the strength of a weld under fatigue than defects. It had been found that on comparing welds made by an automatic process with those made by manual welding that the latter had appeared to be much stronger than the former. The explanation of this was found to be that the hand welding produced a smoother contour between weld and parent metal than the automatic process, where the angle tended to be almost acute.

On the subject of acceptance codes, either in the form of diagrams or radiographs, Dr. Weck declared himself completely opposed to their use. There was not enough basic information available to permit such codes to be devised. So much depended upon particular conditions that it was not to be expected that useful guidance could be given by codes based merely on empirical considerations. No code could be a substitute for a properly educated inspection engineer, with a wide background of practical experience in design as well as inspection.

Information about the Society of Non-Destructive Examination can be obtained from the Honorary Secretary, Mr. H. W. Taylor, Kelvin & Hughes, Ltd., Barkingside, Essex.

"Lead the Enduring Metal"

IN promoting its policy of disseminating information on lead, the Lead Development Association is conscious of its responsibility to foster good public relations and to offer a service to individuals and bodies wishing to improve knowledge, but not requiring to be involved in technical detail. To meet the demands of this section of the community, which vary from those which are satisfied by the normal technical services of L.D.A., the 28-minute colour film, "Lead the Enduring Metal," has been produced. Intended to interest non-technical audiences, the film has been designed to offer general information on lead. After briefly tracing its history and ancient usage, there is a description of the metal's occurrence in the world today and how it is mined, smelted and refined. The main sequences demonstrate the versatile rôle played by lead in the modern world, and deal with applications which include sheet and pipe for building, paints, chemical engineering, lead shot, grids and oxides for storage batteries, type metals for printing, solder, electric cable sheaths and lead glass. Lead's enduring properties and its well-known ability to resist corrosion are demonstrated in connection with its use in several fields. The metal's power to protect against harmful radiation hazards are described with particular reference to hospital and atomic energy plant and equipment. A closing sequence suggest that further new uses for lead will evolve as scientific discovery progresses.

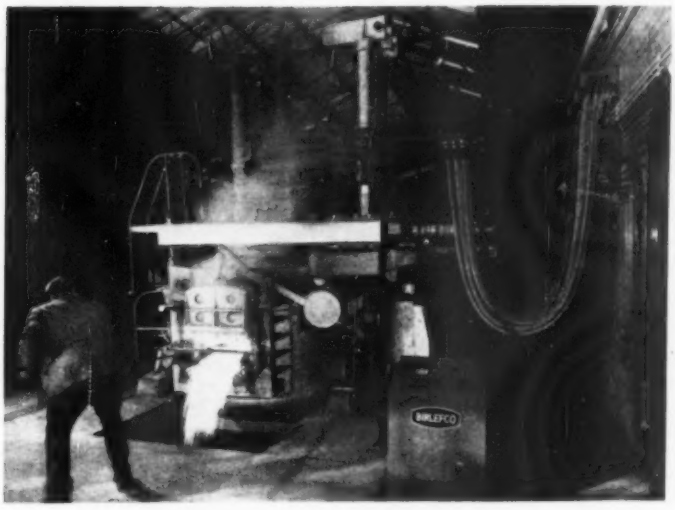
Copies of the film are loaned free of charge on application being made to the Lead Development Association, 18 Adam Street, London, W.C.2.

Change of Address

THE offices and factory of Colloidal Graphite, Ltd., have been transferred to Sheaf Island Works, Pond Hill, Sheffield, 1. (Telephone: Sheffield 27397.)

Cast Iron from Steel Scrap

Ferranti Install 3-ton Birlefco Arc Furnace



Slagging-off the new furnace.

PIG iron used in the production of the wide range of iron castings made by the foundry department of Ferranti, Ltd., at Hollinwood, Manchester, is to be replaced by metal produced from reclaimed scrap steel. This ambitious scheme, which will result in considerable economies being effected, has been made possible by the installation of a new Birlefco 3-ton capacity electric arc furnace. Although electric arc furnaces for the production of steel from scrap metal are quite common today, their use in making iron from scrap steel is a departure from normal practice. Ferranti, Ltd., believe that they are the first heavy electrical engineering company in Britain to put such a scheme into operation.

The scrap to be used consists basically of croppings from transformer laminations and other mild steel. To this material, back-scrap from the foundry, together with a recarburising compound, will be added. This will raise the carbon content to the desired 3–3½%, and there will also be additions of silicon and manganese, the actual amounts depending on the grade of cast iron to be produced.

Types of Iron

One of the materials to be produced in the new furnace will be the company's Nomag, a non-magnetic grey cast iron which was developed by the foundry department in 1923. This material has a high specific resistance and has proved of great value to the electrical industries for the manufacture of resistance grids. Because of its non-magnetic properties, it is widely used by leading British alternator manufacturers for stator end-plates. It has high nickel and manganese contents and is an austenitic cast iron with reasonably high strength. It is anticipated that some 50 tons of Nomag will be produced monthly in the new furnace.

Spheroidal graphite iron, a newer type of cast iron possessing the equivalent strength of mild steel, will also be produced in quantities of about 60 tons per month. By suitable heat treatment the strength can be varied from 25–60 tons/sq. in. It is also ductile, with an elongation varying from 2 to 25%, according to grade. S.G. iron, which was first developed in the laboratories of the British Cast Iron Research Association in 1948, has many general engineering applications. In processing it, the treatment involving the addition of magnesium alloy to the molten metal to change the graphite from flake to spheroidal form, can be rather expensive. The amount required is dependent on the initial sulphur content of the metal, and the lower the sulphur content the less magnesium alloy required. As scrap croppings of transformer laminations contain only 0·02% sulphur, substantial savings will result on this count.

Nodumag is yet another cast iron which will be produced. Basically, this is Nomag with spheroidal graphite, having the same general electrical and non-magnetic properties but with much higher strength—in the region of 28–30 tons/sq. in. tensile strength and an elongation of 15–20%. It is anticipated that about 30 tons of Nodumag will be produced monthly.

The Ferranti foundry department also produces a high strength flake graphite cast iron with tensile strength in the region of 17–18 tons/sq. in.

Advantages of Arc Melting

As is well-known, with the conventional cupola, metal is melted in contact with coke and, as a result, picks up impurities, especially sulphur, from the ash of the coke. Whilst providing a comparatively cheap method of melting which is able to give a continuous supply of molten metal, the cupola has a low degree of efficiency—of the order of 25%—as compared with the 65% efficiency of the electric arc furnace.

The roof of the arc furnace can be slewed hydraulically, exposing the whole of the furnace chamber, and enabling the charging operation to be carried out very quickly using a charging bucket. The high degree of availability obtainable with an electric arc furnace, which is due partly to this technique, is an important feature. Temperature of the molten metal in the arc furnace can be closely controlled, and due to the fact that there are no products of combustion in contact with the metal, the final product is much cleaner than cupola-melted metal.

Flexibility is another important advantage of the arc furnace. A non-continuous practice does not cause any

problems, and with suitable refractories refining techniques for the removal of carbon, sulphur and phosphorus, and certain elements such as manganese and chromium, can be readily carried out. Close control of the composition of the various types of cast iron produced in the foundry is facilitated by the use of the Strohlein apparatus, a new addition to the laboratory which permits the simultaneous determination of the carbon and sulphur contents of a sample obtained from the furnace within five minutes. If it is up to specification, casting can proceed, but if not, the necessary corrections can be made.

Immediately after S.G. iron is treated with the addition of magnesium alloy a sample is taken. It is polished and examined under a microscope to determine that the graphite is in spheroidal form, and it is then checked on the Fuess spectroscope—a further new item of equipment in the laboratory—for residual magnesium content. The latter indicates, primarily, that sufficient magnesium has been added, for too high a magnesium content is undesirable, either on economy grounds or from the point of view of founding properties. Test bars are also cast from all the different types of iron produced in the foundry, which then undergo the necessary physical tests to ensure that they meet customer's requirements.

The New Furnace

The new Birlefco 3-ton capacity 1,600 kVA. electric arc furnace installed in the foundry consists of a cylindrical, refractory-lined, bowl-shaped shell of 7 ft. diameter, with three triangularly spaced electrodes projecting vertically through the removable roof and connected through flexible cables to a furnace transformer. The roof ring in which the roof refractories are seated is water cooled, as are the electrode arms and the clamps in which the 8 in. diameter by 6 ft. long electrodes are held.

Electro-mechanical operating gear in the form of winch motors and counterbalanced wire ropes is provided for each electrode, and control is by means of an amplidyne regulator which maintains a constant arc and a high average power input. Pouring of the metal is simplified by a tilting screw mechanism which can be operated either by an electric motor or by manual means. The furnace tilts on toothed rockers, up to 45° in the forward position for draining the molten metal from the shell, and up to 15° backwards for slagging-off. The furnace is charged from the top by an overhead crane, and batch melting takes about 1–1½ hours.

Because of the arduous atmospheric conditions in the foundry, electrical apparatus—which includes a circuit breaker, transformer and amplidyne set for electrode control—is housed in an enclosed substation adjacent to the furnace. This also contains the furnace control panel, but controls and instruments are mounted on the front of the panel board in the furnace area for easy access by the operator. This control panel is divided into high and low-voltage sections, and is equipped with a Honeywell furnace temperature indicator and Ferranti instruments, which include ammeters, voltmeters, wattmeters, kWh meters, etc.

The 1,600 kVA., 3-phase Ferranti furnace transformer is provided with variable reactance to ensure stable operation of the arc over a wide range of furnace secondary voltages from 230 to 95 V., and to limit the short circuit current which could be caused by an electrode coming into direct contact with the metal charge. The transformer off-load tapping switch is interlocked with the circuit breaker, so as to ensure that the circuit breaker will be tripped if manual operation of the tapping switch is attempted with the transformer alive. Furthermore, the circuit breaker cannot be closed except when the tapping switch is in an operating position. Various other interlocks are provided for the safety of the operator, e.g. the circuit breaker cannot be closed unless the furnace roof is in position.

Although it is too early yet to assess accurately the savings in purchases of pig iron which have been brought about with the installation of the new electric-arc furnace, there is no doubt that it is a considerable time, money and labour saver, and will greatly assist the foundry department towards the goal of increased productivity.

" Only for Men "

" THERE is more to shaving than having a clean shave," says Dr. R. P. Kelvin, of Kellams Research, who has been conducting an investigation into man's reaction to shaving. " A good shave not only leaves the face smooth ; it leaves the man feeling clean and fresh." Dr. Kelvin's studies form the basis of " Only for Men," a new 20 minute Gillette public relations colour film with music composed and played by Humphrey Lyttelton.

Having established the merits of a decent shave with the aid of three main characters—a Guardsman, a young architect and a distinguished surgeon—and a number of interviewees, there is an excellently filmed laboratory sequence followed by a factory sequence which, without any commentary, conveys the vast background of Gillette's knowledge and experience on the subject of shaving. The word " Gillette " is not used once in the commentary and dialogue of the film, but those who see it will be left in no doubt about how to get a decent shave, or that Gillette are the authorities on the subject.

Extended Surface Tube Manufacture

STEWARTS AND LLOYDS, LTD., and Imperial Chemical Industries, Ltd., have agreed to form a jointly-owned company for the manufacture of all kinds of extended surface tubing in steel. The new company will manufacture both Applied Fin Tubing, with a wound-on and welded fin, and Integron integrally-finned steel tubing, the manufacturing facilities for which will be transferred by I.C.I. to the new organisation. Other forms of Integron integrally-finned tubing—in copper, aluminium and bimetals—are not affected by this arrangement and will continue to be made and sold by I.C.I. Metals Division and Imperial Aluminium Co., Ltd.

£120,000 Order from Australia

ELLIOTT BROTHERS (London), Ltd., a member of the Elliott-Automation Group, and Siemens Edison Swan (Australia) Pty., Ltd., announce that they have received orders to a value in excess of £120,000 Sterling, for the supply and installation of electronic recording and control equipment for the Cockle Creek works of Sulphide Corporation, Ltd., in New South Wales. The equipment to be supplied includes a completely integrated weight control and blending system regulating the feed of materials to an I.V. smelting furnace.

Low Pressure Metallurgy
A General Survey

By A. S. Darling, B.Sc. (Eng.), Ph.D., A.M.I.Mech.E.

The carrying out of metallurgical operations in vacuum has more to it than the prevention of oxidation. A metal or alloy concerned in a melting, heat treatment or refining operation may be considered as one component in a polyphase system. Pressure variations add a further dimension to the degrees of freedom previously represented only by temperature and concentration, with the result that equilibrium conditions can frequently be displaced in a favourable direction. In the first part of this general survey of low pressure metallurgy, published in October, the author discussed historical aspects, and in last month's issue he dealt with cathodic sputtering and vacuum evaporation. The survey is concluded here with a consideration of industrial vacuum melting.

(*Concluded from page* 199 *of the November issue*)

INDUSTRIAL VACUUM MELTING

THE development of large scale vacuum melting is inevitably associated with the activities of Dr. Rohn, who directed the pioneer efforts of W. C. Heraeus G.m.b.H. in this field of endeavour. This firm became interested in vacuum melting because of difficulties experienced in the consistent production of base metal thermocouple alloys. Low pressure melting offered the possibility of achieving with base metals the high composition reproducibility hitherto associated only with the noble metal alloys. The first vacuum furnace was constructed early in 1914, but the work was discontinued at the outbreak of war. By December of 1916, however, the platinum shortage in Germany necessitated the resumption of work on base metal thermocouple alloys. The primary object was the production of an *ersatz* couple having electrical properties isuch that it could be used in place of, and with the same instruments as, the 10% rhodium-platinum couple at temperatures up to 1,000° C. This objective was soon achieved, and by May of 1917 base metal thermocouple alloys having temperature scales in close agreement with those of the platinum couple were being produced by vacuum melting.[103] The furnaces first employed for this work were contained in water-cooled copper casings and utilised heavy gauge iridium-platinum heating elements. Two-kilogram charges were melted in crucibles produced from a porcelain type of refractory supplied by the Staatliche Porzellan-Manufacture in Berlin. Melting was carried out at pressures of 1–10 microns.[104]

The general shortage of noble metals in Germany at that period meant that gas-free base metals were in considerable demand. Vacuum melted metals were of particular value for false teeth production, because they could be fired into ceramic masses without causing undue porosity. Vacuum melted metal was also sold for sealing into glass and for X-ray targets, etc. Larger melting furnaces were constructed to cope with these increased demands. Early in 1918, one capable of casting 20 kg. ingots was in regular operation, and a 40 kg. furnace fitted with molybdenum resistance elements was in use shortly after the end of the war. This furnace, described by Hessenbruch and Schlichtel,[105] was employed for vacuum melting nickel-chromium alloys.

Production of Pure Iron

Much valuable experience was obtained during these wartime developments, and the published information indicates that vacuum melting was, even at this early date, regarded not merely as a somewhat cumbersome method of avoiding oxidation.[106] A process developed for the production of very soft iron used mild steel as a raw material, and depended upon low pressures to drive the reaction between iron oxide and carbon to completion.[107]

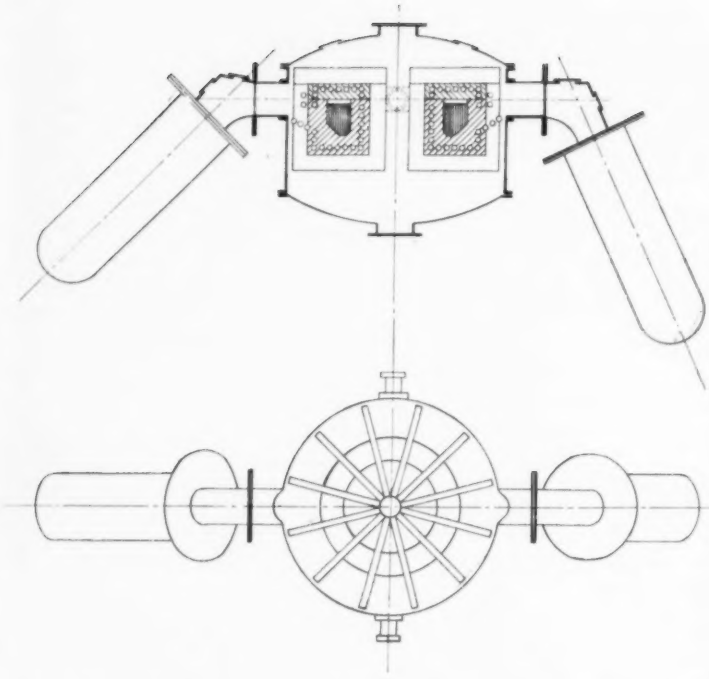
The steel was melted and degassed in vacuum, after which, silicon, manganese, and other impurities were oxidised and carbon partly removed by an oxygen-rich gas mixture which was introduced into the furnace. The carbon—iron oxide reaction was allowed to proceed to completion under low pressure conditions, after which any excess iron oxide was reduced by the addition of either hydrogen, zinc or sodium. Final vacuum treatment volatilised any excess of these deoxidants, and the pure iron was cast into ingots. Iron so produced had a hardness of 52 Brinell, and was comparable in ductility to copper. Plans to use it as an *ersatz* driving band material were discontinued when the war ended.

Rohn's patent claims of January 1918[108] summarise what must still be regarded as the primary objectives of vacuum melting operations. He emphasises that the metal must be held heated, or molten, *in vacuo* until all dissolved gases are removed and internal reactions leading to the evolution of gas or vapours are driven to completion. Certainty that this objective has been achieved is possible only when no rise in furnace pressure occurs when the pumps are sealed off. It is significant that, although this point was accentuated in many of Rohn's publications, no definition of what constituted a negligible pressure rise was ever advanced. In practice, however, the criterion must have been applied with considerable success, as even in 1917 reasonably accurate measurements of the total amounts of gas evolved during the melting of metals of commercial purity appear to have been made.[104]

Resistance Heating Alloys

At the end of the war attention seems to have been concentrated upon the production of high grade resistance heating alloys, for which there was a great demand.

Vacuum melted nickel-chromium alloys were easier to draw into good fine wire than air melted material, and the improved metallurgical cleanliness of the vacuum product ensured a longer high temperature working life.[109] These two factors compensated in some instances for the added expense of vacuum melting, and gained for the process a somewhat limited economic success in what was



Courtesy of The Institute of Metals

Fig. 3.—Low-frequency induction furnace used by Rohn for vacuum melting nickel-chromium alloys.

at the time a highly specialised and competitive field. 80/20 and 65/15/20 alloys were produced, and it was claimed that the operating life of the vacuum melted 80/20 material was considerably longer than that of similar material melted under hydrogen by Smithell's process.[110]

Resistance heated furnaces were unsuitable for vacuum melting on a large scale, and Heraeus constructed a 300 kg. low-frequency furnace of the Kjellin type in 1921. The last molybdenum heated furnace, which also had a capacity of 300 kg. was constructed in 1924.[105] By this time, however, the scale and direction of the vacuum melting operations then being pursued had led to the formation of a separate organisation for their more efficient development. Heraeus Vacuumschmelze Aktiengesellschaft was founded in 1923 in the middle of the inflationary period.[103] Rohn estimated ten years later that its initial working assets had a value in gold equivalent to 1,100,000 marks.

Low-Frequency Induction Furnaces

The factory was finished in July of 1923 and construction of the first vacuum induction furnaces was completed the same year. The rate of development was such that 4,000 kg. furnaces capable of casting two 2,000 kg. ingots were in regular operation by 1928. The general design of these large furnaces, having been described by Rohn in several papers,[104,111-113] is well known. Fig. 3 illustrates the essential features of a furnace capable of utilising a maximum power of 350 kW.

The primary coil of water-cooled copper tubing was divided into four sections which were embedded into the refractory of the annular hearth : the bath of molten metal was therefore completely surrounded by cooled tubing. The design of iron yolk differed from that employed in the Kjellin type of furnace,[114] insofar as it was divided into a number of radially distributed sections. By this method a very uniform magnetic field which minimised induction heating effects in the copper casing was obtained. In order to obtain rapid melting all the four primary coils were connected in series, thus producing a strong uniform magnetic field which introduced little stirring action into the melt. Turbulence was introduced into the bath when required by the non-uniform field resulting from the use of one coil only.

Hearth Production and Ingot Casting

Operating experiences with these larger furnaces resulted in the development of improved techniques for both hearth production and ingot casting. The necessarily intermittent operation of a vacuum furnace imposed greater thermal stresses upon the refractories than those which occurred in air melting processes, where, by suitable operating techniques, the hearth could be kept at a reasonably uniform temperature. When produced by conventional techniques, the hearths of these low-frequency vacuum induction furnaces had an uneconomically short life. Furthermore, the bonding materials employed evolved large volumes of volatiles which made it difficult to maintain a satisfactory vacuum. Efficient hearths were produced by fritting from a dry fused granular refractory material within a metal mould inside the furnace.[115] Hearths of silica, fused alumina, or magnesia fritted *in situ* with small admixtures of powdered glass or open hearth slag were produced by this method. The economics of resistance alloy production by vacuum melting were dictated entirely by hearth life, and the continued use of this method depended on the adoption of such hearth production methods, which were employed at a slightly later date for lining most types of mains- and high-frequency coreless induction furnaces.

The absence of blowholes in ingots cast from properly degassed metal meant that shrinkage cavities were not camouflaged to the extent common with air melted material. Very large shrinkage cavities occurred in all vacuum cast ingots which had been poured at conventional rates.[104] The magnitude of such shrinkage cavities was obviously proportional to the amount of liquid metal present in the ingot mould at any time. This quantity varied directly with the pouring rate and inversely with the rate of heat extraction from the ingot.

Very satisfactory results were obtained by the use of very low pouring rates and by employing water-cooled copper ingot moulds of special design.[104,116] Pouring time for a 2,000 kg. ingot was 40–60 minutes, and a 300 kg. ingot took 12–18 minutes. Such ingots showed no signs of either micro- or macro-porosity. Vacuum conditions favoured the production of ingots by this slow pouring technique because the thin stream of metal

Courtesy of The Institute of Metals

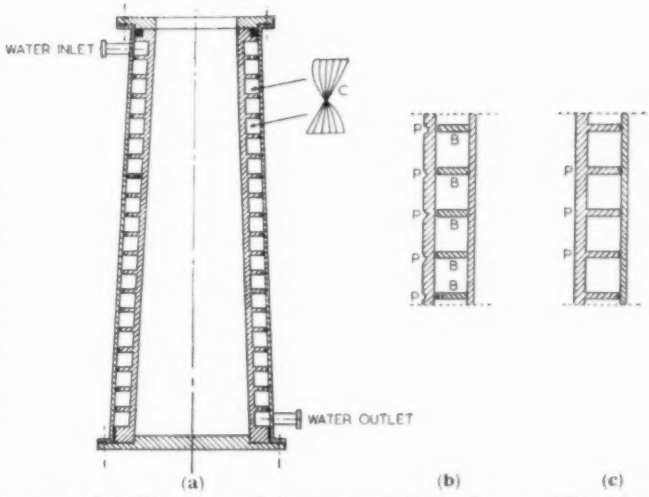


Fig. 4.—Water-cooled copper ingot moulds used by Rohn for the vacuum casting of nickel-chromium alloys.

neither oxidised nor lost excessive heat by conduction.

The severity of working conditions to which moulds used *in vacuo* are subjected is due to the absence of a protective gas blanket between mould wall and ingot. Rohn found that when water-cooled moulds were constructed as shown in Fig. 4*a*, the mould walls at places indicated by *P* were damaged by the molten metal because of insufficient cooling at these points. Complete success was achieved when moulds were machined from thick walled copper tubing as shown in Fig. 4*b*. A number of propeller-shaped bodies *C* were inserted into the water channel to ensure a more efficient scrubbing action against the mould walls. Moulds produced in this manner had a life of more than 1,000 ingots when dealing with nickel-chromium alloys which were cast in the temperature range 1,560–1,680° C. The surface quality of such ingots was very high and no machining was required before rolling.

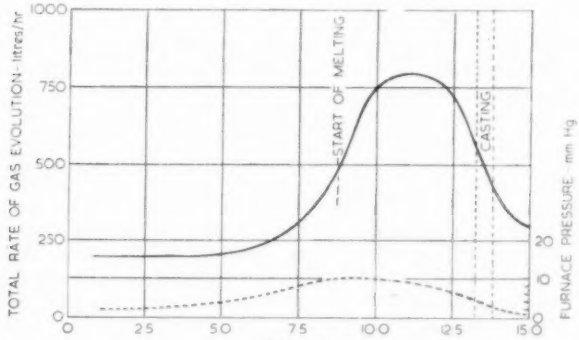
Composition and Quantity of Evolved Gases

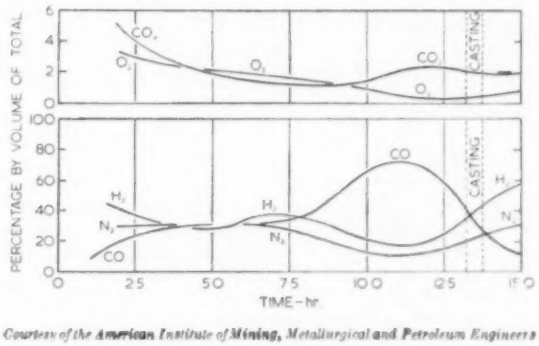
This pioneer work by Rohn gave adequate demonstration of the very large volumes of gas evolved when commercially pure metals were heated *in vacuo*. Extraction times, with the pumping equipment available at that period, were correspondingly lengthy. One example[111] relates to a nickel-chromium charge having a total weight of 3,500 kg. 500 kg. were first melted *in vacuo* and allowed to solidify, after which the remaining 3,000 kg. were charged. Detailed measurements of the composition and quantity of the gases extracted were made during the rest of the melting and casting cycle, which lasted fifteen hours. Fig. 5 illustrates the results obtained. During the early stages of heating, gas was being extracted at a rate of approximately 200 litres per hour at N.T.P., the vacuum maintained during this period being of the order of 2–3 mm. Hg. The rate of gas evolution increased with temperature and after nine hours of heating, when melting had commenced, approximately 500 litres were being extracted per hour. After the metal had been kept molten for three hours, the rate of gas evolution fell to a low constant value and the ingots were cast. A maximum furnace pressure of 10 mm. Hg occurred during the melting process, and casting was carried out at a pressure of about 4 mm.

During the early stages of heating, hydrogen represented approximately 40% of the total gases evolved. This value decreased slowly, however, and reached a minimum of 16% halfway through the melting cycle, when carbon dioxide represented 70% and nitrogen 10% of the evolved gases. The proportion of oxygen, initially about 3%, decreased gradually to less than 0·5% after 11 hours heating.

The total volume of gas evolved during the complete melting and casting operation was approximately 5,060 litres, measured at N.T.P. This represented a gas content of 2·6 litres/kg. of metal melted. In a similar instance, 1·35 litres of gas were extracted from each kilogram of nickel-chromium melted in the same furnace.

In spite of obvious errors relating to the stability of certain metallic oxides (it was claimed,[111] for example, that at pressures below 6 mm. Hg, nickel oxide decomposed at 1,500° C.) the technical level of this paper by Rohn must have been much in advance of current





Courtesy of the American Institute of Mining, Metallurgical and Petroleum Engineers

Fig. 5.—Composition of gases extracted during the vacuum fusion and casting of a 3,500 kg. charge of nickel-chromium alloy: (a) rate of gas evolution (continuous curve) and furnace pressure (dotted curve); (b) composition of gases at various stages.

practice. The effect of pressure on the balance between oxygen and carbon in steel was dealt with, and the advantages of determining the total gaseous content of metals by vacuum fusion in a bath of iron saturated with carbon discussed.

In 1927 Heraeus put in hand the construction of what was probably the first large coreless induction furnace to be built in Germany.[103] This furnace, which could utilise 200 kW., was first used for normal air melting processes. The advantages of this type of furnace for vacuum work were soon appreciated, however, and by 1931 several high-frequency vacuum melting furnaces capable of melting 4,000 kg. charges were in regular operation.[117]

The linings of these furnaces were produced by a fritting method similar to that previously employed for hearth manufacture on the large low-frequency furnaces. The techniques employed have been described in detail by Motock.[117] A layer of electrically fused magnesite-magnesia mixture incorporating 2% of powdered glass or open-hearth slag for bonding purposes was tamped into the water-cooled copper coil. Fritting was carried out with a 0·4 in. thick mild steel template which was calculated as part of the first charge. These furnaces were provided with a separate high-frequency tapping coil for ingot casting by the bottom-pouring method.

Materials melted in this type of furnace ranged from ferro-chromium and stainless steels to nickel-chromium and alloys of beryllium with nickel and copper. Work on the properties of high permeability nickel-iron and silicon-iron alloys, undertaken initially in collaboration with the Physikalischen-Technischen Reichsanstalt, began in 1927, and it was soon found that alloys of this type were advantageously melted *in vacuo*.

Heraeus were involved in the beryllium project of Siemens and Halske for some time before 1933, and by that date considerable experience had been gained in the beryllium-copper and beryllium-nickel fields. Vacuum melting techniques led to considerable economies in the use of beryllium; Hessenbruch[118] showed, for example, that a vacuum melted nickel alloy, to which 1·7% of beryllium had been added had properties equal to that of an air melted alloy having a nominal beryllium content of 2%.

Nivarox, a beryllium-containing hairspring alloy, was regularly produced by vacuum melting processes. Based on an earlier nickel alloy developed by Guillaume,[119] it could be age hardened and had a very low temperature coefficient of elastic modulus. The full list of vacuum melted alloys produced during this period has been described by Motock[117] in considerable detail.

Economic Aspects

Siemens and Halske acquired Heraeus Vacuumschmelze in 1936, and this year forms a convenient stage at which to pause and attempt some assessment of the value of the vacuum melting activities at Hanau. There is little doubt that enthusiasm for the technique occasionally suggested vacuum melting when this was not really necessary, and that in other instances the balance between increased price and increased quality did not always favour the vacuum melted product. It was soon found, for example, that beryllium alloys could be satisfactorily melted in air, and that the small economies in beryllium consumption did not always justify the increased cost of vacuum melting.

Although the decarburisation of stainless steel in vacuum was found to be uneconomic, considerable advantages were associated with the same technique when applied to the production of electrical resistance alloys. Vacuum melted nickel-chromium alloys were undoubtedly superior to those produced by conventional methods. Both in the cast condition and also after hot and cold working, they were softer and less notch sensitive than the same alloys produced in an arc furnace. The high temperature service life of vacuum melted material was considerably superior even to that of material melted in hydrogen by Smithell's technique.

The economics of vacuum melting were, according to Rohn, largely dictated by the durability of the hearths employed. When melted in 4 ton quantities the increased cost of vacuum melted nickel-chromium alloys amounted to 10 cents/lb. of ingot cast,[111] and this meant that the process could only be justified for the production of material which was intended to be drawn into fine wire. The increased cost was largely due to the limited furnace output, because the limited pumping capacity available meant that long melting cycles were required. Radical improvements in furnace output were not possible without the aid of large capacity vapour pumps, which did not become available until after 1945.

Undue concentration upon economics tends to obscure the true importance of this pioneer work by Heraeus. The developments at Hanau fall into truer perspective when considered as a project for studying the feasibility of large scale vacuum melting under rather unfavourable technical conditions. The degree of economic success achieved within these limitations affords adequate confirmation of the soundness of the principles involved and the possibilities of the technique.

More Recent Developments

Apart from the pioneer work just described, vacuum melting was carried out on a very restricted scale in the years immédiately before the second World War. Scholefield[120] recently commented that Heraeus Vacuumschmelze and The Telegraph Construction and Maintenance Company were the only two firms regularly to melt and cast metals under reduced pressures before 1939. The furnaces at the latter firm were of the high-frequency type, and were evacuated by rotary oil-sealed pumps, and pressures at casting ranged from 0·5–5 mm. Hg.

There is little record of any industrial vacuum melting processes in America over the same period, and there was certainly nothing comparable in magnitude to the activities in Hanau. Small vacuum melting furnaces powered by Northrup spark-gap equipment were frequently employed.[121] Melting was carried out in an evacuated silica tube, using an external high-frequency coil, and charges up to 5 lb. were handled.

The absence of suitable large capacity diffusion pumps undoubtedly frustrated many attempts made at this period to develop industrial vacuum melting equipment. Most of the early experimental furnaces were unsuccessful because of inadequate appreciation of the volumes of gas which would have to be handled. Engineering problems connected with attainment of perfect gas tightness had been approached in too casual a fashion, with the result that no really satisfactory solutions had been reached.

Much of the credit for the rapid development of large pumping equipment and for the evolution of satisfactory techniques for the design and construction of very large vacuum plant must undoubtedly be ascribed to wartime

atomic energy developments. As a result of these developments it became possible for the first time to build vacuum plant of large capacity which could be regularly operated without difficulty at pressures below 10^{-4} mm. Hg.

When the Bureau of Mines commenced its now classical research programme on the production of ductile titanium,[122] satisfactory methods existed for melting, sintering and heat treating this metal under conditions which avoided atmospheric contamination. These techniques were used at a slightly later date for melting zirconium.[123]

Increasing awareness of the effect of hydrogen content upon the mechanical properties of numerous commonly employed alloys was a logical outcome of the improvement in vacuum metallurgical techniques. The improvement in impact strength resulting from the vacuum melting of a 28% nickel steel was attributed by Hochman[124,125] to the elimination of hydrogen. The fact that hydrogen was responsible for the flaking which frequently occurred when large steel forgings were being cooled had been recognised by investigators at Krupps as early as 1935.[126,127] This recognition led to numerous attempts to reduce the hydrogen content of large baths of molten steel. Bochumer Verein appear to have been very successful in achieving this objective. Progress in their method of degassing by the stream droplet technique has been described by Tix.[128] The results obtained have apparently been quite spectacular, and hydrogen contents of less than two parts per million have been achieved. Since 1952 Bochumer Verein have produced more than 25,000 tons of vacuum degassed steel in ingots weighing up to 150 tons.

Progress in this field has been achieved so rapidly that it is difficult to view the subject in its true perspective. Recent developments will be reviewed in detail in a later article.

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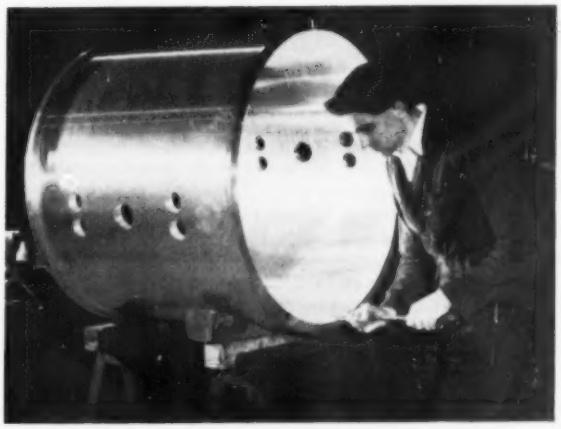
Aluminium-Tin Alloys for Bearings

LOW-TIN-CONTENT aluminium alloy has been used for bearings in place of conventional materials, such as Babbitt metals (both lead- and tin-based) and bronzes, for a number of years in Europe and the United States, and it is being increasingly used in this country. Davy and United Engineering Co., Ltd., are now offering aluminium-6½% tin alloy bushes in their Morgoil specialised bearing system for rolling mills as an alternative to white-metal steel-backed bearings, since aluminium-tin alloy has been found to be technically and economically acceptable for specialised applications such as this.

Morgoil bearings with aluminium-tin bushes have been fitted on the back-up rolls of 7 ft. and 12 ft. steel rolling mills in this country. One mill has recently completed three years' service, during which time more than 700,000 tons of steel were rolled, and when the bearings were examined they were found to be in good condition. Bushes for bearings of this type are cast from Noral 730 aluminium alloy supplied by Northern Aluminium Co., Ltd. this alloy being particularly suitable as a bearing material where high loadings and speeds are encountered, and where adequate lubrication is available. The illustration shows a bush, 36 in. in diameter and weighing 800 lb., for a 7 ft. mill. Other ferrous and non-ferrous rolling mills in this country and in Europe have been fitted with aluminium-tin bushes, either as part of a specialised bearing system, such as Morgoil, or as plain bearings.

Noral 730 contains 6½% tin, 2½% silicon and 1% copper, with the remainder aluminium; it has a 0·1% proof stress of 4 tons/sq. in., an ultimate tensile stress of 10 tons/sq. in., and has been specifically developed for solid bearings, i.e. bearings that do not need a backing material to give strength. The qualities of tin as a bearing material are combined with the strength of aluminium to give excellent wearing characteristics. With a thermal conductivity three times greater than that of steel and five times greater than Babbitt metal, Noral 730 is plastic enough to conform to any normal misalignment, it embeds particles easily and is therefore highly suitable for heavy duty machinery such as rolling mills. These properties enable it to be used at lower cost in place of brass for bushes in diesel engines, hydraulic presses and pumps, electric motors, cranes, dredgers, lathes and combine harvesters; applications that have been successful in the United States, but the majority of which are as yet untried in this country.



Bearing bush in aluminium-tin alloy for a steel rolling mill.

Heat Treatment in Nitrogen-Hydrogen Atmospheres

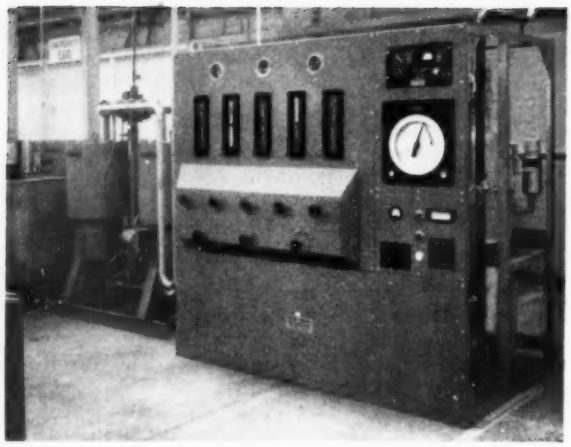
Applications of Nitroneal Generator

WHERE it is desirable that metals should be heated in an inert or reducing environment, the use of atmospheres containing hydrogen and or nitrogen has been established for a long time, and bottled gas and ammonia cracked by a dissociator adjacent to the furnace have been widely used for this purpose. An improved source of such atmospheres—the Nitroneal generator manufactured by Engelhard Industries, Ltd., Baker Platinum Division—is now finding increasing favour with manufacturers. This item of equipment produces a nitrogen-hydrogen gas mixture by reacting ammonia with air in the presence of a platinum group metal catalyst, and is available in two sizes, supplying up to 500 or 1,500 c.f.h. Since the nitrogen is drawn from both air and ammonia, these generators produce a larger quantity of gas for each pound of ammonia consumed than is possible with a simple ammonia cracker, and, of course, at appreciably less cost than bottled gas.

The hydrogen content of the Nitronel gas can range from 25% down to 0·5% or less, and can be varied by automatic or manual control of the air-ammonia ratio. Once the most suitable hydrogen content for the process in hand has been decided upon, the gas composition leaving the Nitroneal generator will remain constant within 0·25% of the set point. This is achieved by using a Honeywell Brown Electronik recorder controller, which is coupled to a built-in analyser. When a new batch of material, calling for a different gas mixture, requires processing, it is a simple matter to alter the hydrogen-nitrogen relationship.

Among users of Nitroneal generators in the United Kingdom are Messrs. Ranco of Uddingston, near Glasgow, manufacturers of thermostatic controls. This company has one 1,500 c.f.h. Nitroneal generator supplying two EFCO hump-back furnaces, which are used for the brazing of small parts, the usual materials being brass and copper in the thickness range of 0·030–0·034 in. This process requires a furnace temperature of 1,000° C., and a gas mixture of 15% hydrogen and 85% nitrogen with a dew point of −30 to −40° F., the latter being obtained by means of a dryer. With this installation, Messrs. Ranco have been able to carry out work of a consistently high quality, and this is attributed largely to the fact that the gas produced by the Nitroneal generator is completely clean and consists only of nitrogen, hydrogen and a small amount of water vapour which is removed by the dryer.

Other Nitroneal users operate at minimum hydrogen concentrations which, under favourable conditions, can be as low as 0·25%. Such atmospheres are frequently required for blanketing chemical processes, and here again, the high purity of the gas produced by the Nitroneal generator makes it especially suitable.



A view of a 1,500 c.f.h. Nitroneal generator at the Uddingston Works of Messrs. Ranco, Ltd. Two dryers may be seen on the left of the generator and a part of one of the two EFCO hump-back furnaces is shown bottom left.

A most important factor, in equipment of this type, is that starting and operation should be simple and take up only a minimum amount of the furnace or process operator's time. The automatic control incorporated achieves this highly desirable feature, and its robust construction makes for freedom from maintenance and servicing worries.

Titanium-Clad Vessels

A TITANIUM-CLAD pressure vessel of commercial size, built in 1959 year by Chicago Bridge & Iron Co. for a petrochemical firm, has now withstood many months of strenuous service, and the company is now prepared to build titanium Hortonclad vessels on a commercial basis, thus opening the door for the use of titanium-clad vessels throughout the chemical, petrochemical, paper and other processing industries. Such vessels provide titanium's remarkable corrosion resistance at considerably less cost than that of solid titanium structures.

The titanium-clad vessel installed in California was designed for a working pressure of 150 lb./sq. in. at 500° F. (260° C.). It measures approximately 4 ft. in diameter by 12 ft. high and was fabricated from plates of $\frac{1}{2}$-in. mild steel clad with $\frac{5}{64}$ in. and $\frac{7}{64}$ in. grade A-40 titanium. Hemispherical heads, top and bottom, were each welded from pressed segments: fittings and flanges were titanium-lined. The vessel is the outcome of a long period of research and development which included the design and construction of a small titanium Hortonclad pilot vessel, and its operation for more than a year to test the welding techniques eventually used on the first full-size structure. During the course of this work, procedures were developed to prevent contamination of the titanium cladding by the steel backing plate; forming problems were solved; and ways were found to vacuum-clad in titanium at sheet sizes comparable to sheets of conventional corrosion resisting metals. Clad sheets up to 5 ft. by 7 ft. were used on the first vessel.

Iron and Steel Research

BISRA London Laboratories' Open Days

(*Continued from page 216 of the November issue*)

Chemistry Department

Corrosion

Some five years ago BISRA formed the Corrosion Advice Bureau to assist engineers and industrialists faced with corrosion problems, and its services are available to discuss the best methods of protection for new plant as well as for investigating corrosion failures. Advice is, in general, given free to members of BISRA but where experimental work is involved or where the enquiry emanates from a non-member, a fee may be charged according to the time and work entailed.

Research on corrosion is necessarily a slow business, particularly where field tests are concerned. Laboratory tests may be divided into two groups; (*a*) tests to simulate actual conditions of field exposure: and (*b*) accelerated tests. The first group includes simple humidity tests and those carried out with the BISRA rotor apparatus, which has been designed for tests on specimens immersed in liquids, especially sea water, and moving at rates up to 15 knots. An interesting item of testing equipment is the slow rotor apparatus, built to investigate the inhibitive properties of various compounds since static tests proved inconclusive. Based on an older N.C.L. apparatus, the design has been modified so that the specimens revolve as well as rotating, and the consequent absence of a leading face prevents preferential action. Caution is necessary in interpreting the results obtained from accelerated tests, but they are useful in predicting the comparative performance of coatings for specified purposes: two of the most-commonly used tests of this type are the C.R.L. sulphur dioxide test and the A.R.E. salt-droplet test.

Corrosion in air is of considerable importance in the U.K., where the humidity lies about 70% throughout most of the year, and where pollutants such as sulphur dioxide and soot are frequently present. Exposure tests in atmospheres varying from industrial to marine have shown that one of the best priming paints consists of aluminium basic lead sulphate in alkyd medium, whilst test panels on a tropical surf beach in Nigeria have demonstrated the successful protection afforded in such conditions by a 3 mil. sprayed coating of zinc or aluminium. The protection of steel by a metal coating depends on the thickness of the latter, and the reproducibility and accuracy of thickness testing instruments is being examined by laboratory tests.

The corrosion rates of ordinary steel and of copper-bearing steel do not differ appreciably when totally immersed in sea water, but tests extending over five years have established that the corrosion rate was roughly halved by the addition of 3% chromium. Raft tests and service trials have established as one of the best anti-corrosion paint for ships' bottoms a composition pigmented with basic lead sulphate, aluminium, Burntisland red and barytes, bound with a modified phenol formaldehyde resin / stand oil / tung oil medium. Investigation of methods of preparation of new plates before painting has shown that the best results are obtained by removing all millscale by grit blasting or pickling; weathering for a few months; and wirebrushing thoroughly immediately before applying a pretreatment primer.

In a study of the durability of buried iron and steel, field tests have been made on: (*a*) iron and steel pipes, with and without protective coatings; (*b*) bare nodular irons; and (*c*) iron and steel protected by hot dipped tar and bitumen coatings. A slate-filled coal-tar pitch has proved to be the best coating after five years burial in aluvium at Benfleet, but the degree of protection of any coating depends largely on its thickness. The relative corrosiveness of various soils can be compared in the laboratory by the Denison cell test, in which two steel electrodes (one perforated) are separated by a layer of moist soil. Differential aeration is achieved by making one of them more accessible to air than the other. The current through the cell is measured at intervals and the results plotted: at the end of the test the weight lost by the anode is determined. The results depend on the water content of the soils, and the conditions of testing have to be carefully standardised and controlled.

Iron-Chromium-Nitrogen Alloys

The solubilities of nitrogen in pure iron-chromium alloys containing up to 30% chromium have been determined at temperatures from 900° to 1,400° C., by equilibrating the alloys with nitrogen at certain partial pressures. The results show that chromium increases the solubility of nitrogen in iron. The part of the $\alpha-\gamma$ phase boundaries in these alloys has been determined, and it has been shown that the effect of nitrogen on the position of the $\gamma/\gamma+\alpha$ boundary is very similar to that of carbon.

The study is now being extended to measurements of the mechanical properties of these alloys. An iron alloy containing 28% chromium was nitrogenised to three levels of nitrogen (0·45%, 0·78% and 1·1%), quenched in water from 1,200° C., and tempered at 150°, 300° and 450° C., after which Hounsfield Tensometer and Vickers micro-hardness tests were carried out. The results to date indicate that the tensile properties can be improved considerably by the introduction of nitrogen, and an increase in toughness is obtained by quenching the alloys from 1,200° C., where the metal is partly or completely austenitic, depending on the nitrogen content. Between 0·2% and 0·9% nitrogen, the structure consists of ferrite and austenite, and above 0·9% it is wholly austenitic. When water-quenched, the austenite is retained at room temperature, and no decomposition of the phase was noted on heating at temperatures up to 450° C., for an hour. Metallographic examination and micro-hardness testing is still in progress.

Sulphur Pick-up during Scrap Steel Melting

As a first step in an attempt to discover the factors influencing the rate of pick-up of sulphur in scrap melting and refining, measurements are being made on the rate of sulphur transfer from gas to slag. So far, experiments have been carried out at 1,550° C. with $CaO–SiO_2$, $FeO–Fe_2O_3–SiO_2$ and $CaO–FeO–Fe_2O_3–SiO_2$ slags, the gas passed over being a mixture of three parts of CO to 1 part of CO_2 and 2·8% SO_2. Although small samples were used it took 4–5 hours to reach equilibrium. In ferrous silicate melts there was a rapid increase in the sulphur content during the first hour, but after longer reaction times the sulphur content of the slag decreased to the equilibrium value: this is believed to be caused by the increasing ferric oxide of the slag with increasing time of reaction. For given sulphur and oxygen potentials and a given silica concentration, replacement of lime by iron oxides increased the solution of sulphur in the slag. This work is still in progress, and no further conclusions can yet be drawn.

Physics Department

Automation of Surface Inspection and Finishing of Rolled Steel Sections

Rolled steel sections intended for re-rolling are at present inspected by eye for surface defects, and the faulty portions of the surface are removed by grinding, chipping or de-seaming. The tools for repairing the surface are usually operated by hand and the material is lifted on and off stacks by crane and put in position for treatment by hand. For example, 30 ft. long billets for de-seaming are lifted in bundles from a stack and laid on the floor. Working in pairs, operators lay the billets out side by side and de-seam any faults they see on the uppermost faces. They then roll the billets over to treat the next face. When all four faces have been treated, the billets are taken by crane to form a new stack ready for despatch.

With this procedure the de-seamers spend a large part of their time handling billets and waiting until the bundles are moved by crane. It also requires a large amount of floor space, since each pair of operators needs floor area corresponding to approximately 2½ stacks; one is for material to be treated, one for finished lengths and the remainder for the actual de-seaming operation. It is estimated that the cost per ton of de-seaming could be significantly reduced by introducing some form of mechanisation. The system described here, has been developed by the Physics Department and is to be tested at a member firm's works.

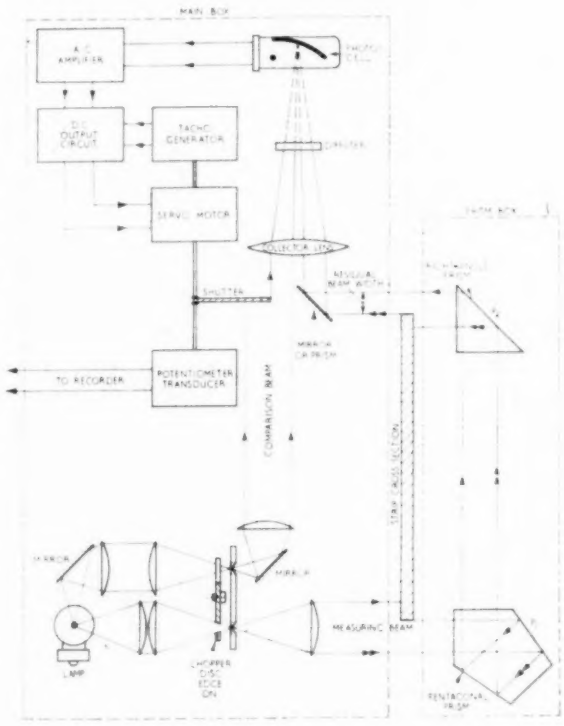
The cooled 30 ft. long billets are laid in bundles on a roller table and presented in turn to two men who inspect the uppermost faces simultaneously, and mark the positions of faults with chalk. Each billet is then turned over mechanically to present the remaining faces. After inspection it is released and falls into one of three channels: (1) no further treatment required; (2) further treatment required; and (3) reject or scrap. Immediately a billet is released after inspection it is replaced by another.

The billets in channel 2 are taken by rollers on to a de-seaming bed where they are treated in groups, much as at present, but turned over mechanically. Those in channel 1 fall on to a bed solely for storage. The billets are then taken to the dispatch bed from the de-seaming bed and from the channel 1 store in their original order. In this way the original bundles are reformed (less any that have been scrapped).

The scheme of mechanisation outlined above forms the first stage of the possible evolution of a fully automatic system. By using fluorescent penetrants a good picture of the faults can be obtained when viewed by photo-cells under ultra-violet light. The output signals from these cells could then trigger the finishing mechanism, applying the finishing job to the four faces simultaneously or in close succession. Preliminary studies suggest that worthwhile savings would result from these developments.

Optical Forging Gauge

The dimensions of large hot forgings cannot easily be measured by manual contact methods, since they are too hot (e.g. 1,100° C.). BISRA is therefore developing an optical caliper that can be used from a distance of about 15 ft. Each end of the forging is viewed through a prism. The two prisms are mounted on adjustable carriages; they can then be moved along a base line until the distance between them is equal to the distance between the ends of the forging. The images of the edge of the forging are combined in a single field of view, and are transposed so as to point to each other. When the edges of the two images coincide, the prisms are correctly adjusted; if the images overlap or fail to meet, the prisms are incorrectly adjusted. The inclusion of a "telecentric" optical system ensures that accuracy is unaffected by distance between the instrument and forging. The base line carrying the prism is fully adjustable to allow the forging to be viewed from any



Schematic diagram of width meter.

direction. The image can be presented on a closed-circuit television screen and this has the advantage that the operator can view it from any convenient position.

Bar-Section Meter

This instrument has been designed to measure simultaneously four diameters or hot solid bar at 45° intervals across the section while it is moving at high speeds. This information is valuable not only for checking that the section is being rolled to the specified size, but also for early detection of such defects as finning. The water-cooled viewing head forms images from the opposite edges of the bar across each diameter to be measured. These images are combined in a single field of view, and are magnified and transposed so as to point towards each other. The instrument thus shows four parallel bands of light representing the four diameters measured. Each nominal diameter of the bar is set on the instrument by a micrometer adjustment; if this corresponds to the diameter being viewed, then the appropriate band is continuous across the field of view, i.e. the fact that the edge images have been brought to coincidence in any band indicates that the diameter is as set. If there is a gap in the middle of the band the diameter is less, while a bright central zone caused by the images overlapping indicates that the diameter is greater. First experiments show that deviations in diameter of about 0·005 in. can be detected. The instrument is designed for mounting on a mill run-out table, the viewing telescope being offset to give convenient access. Guide rolls on the work piece are necessary to keep it from vibrating when in the field of view.

Precision Width Meter for Narrow Hot-Rolled Strip

Narrow strip for tube making is rolled to close tolerances in a hot mill, usually of the Morgan type, and leaves the last stand at 1,200–2,000 ft./min. and at a temperature of 900–1,000° C. Inaccuracies can lead to faults in the final product, and a non-contact method of determining width as the strip leaves the mill, has been developed, measurement being made whilst the strip is moving at speed with its plane vertical. A certain amount of transverse vibration occurs as the strip moves along its guide, but the width meter allows for this in making its measurement.

The principle of the method is that the width of the strip is measured by the extent to which it interrupts a parallel beam of light. The system is illustrated in the diagram. By using a pentagonal and a right-angled prism to reflect the beam round three sides of a rectangle, the two edges of the strip are made to obstruct opposite edges of the light-beam, so that lateral movements of the strip are automatically compensated for. Light from a concentrated source is formed into two beams and a "chopper disc" is used to interrupt each in turn. Light thus falls on the photocell alternately from the "measuring" and "comparison" beams. If the intensity of the two beams is not equal, an A.C. signal is generated by the photocell; this current is amplified and made to drive a servo-motor which moves a spiral shutter to restrict the "comparison" beam until a balance is attained. The shutter is connected to a potentiometer which operates a chart recorder with a high speed of response or provides some other suitable display.

The equipment is mounted in two boxes which are carried on a very rigid metal frame in the shape of an inverted U. The problem of atmospheric pollution is overcome by an air-purging system. Clean air is forced by a blower through cells mounted in front of the windows through which the light beams pass.

On trials in the works a prototype instrument proved accurate to about 0·005 in. and showed a speed of response of a tenth of a second, corresponding to about 2–3 ft. of strip. Variations in the width of the strip were measured over a range of $\frac{1}{8}$ in. and a lateral movement of up to $\frac{1}{4}$ in. each way could be accommodated. These figures do not necessarily represent the ultimate performance of which an instrument of this type is capable.

The system can be adapted for measuring strip up to 18 in. wide, the optical and electronic equipment remaining unchanged. The modifications required are confined to the air-purging system and mechanical arrangements for moving two optical components. An instrument incorporating these modifications is now being manufactured by the Davy and United Engineering Co., Ltd.

Continuous Detection of Laminations in Steel Strip

Laminations in steel sheet result if defects such as piping, blow-holes, or segregation were present in the ingot from which the sheet was rolled. During rolling, such flaws become flattened and elongated, and the sheet which finally emerges from the mill contains internal discontinuities parallel to its surface. These may be from a fraction of an inch to several inches wide and from an inch or two to several feet long.

It is important to have some means of detecting the presence of laminations in steel sheet. In deep drawing or pressing, for example, a laminated sheet may burst in the press and cause considerable damage to dies and tools and disrupt production. Unfortunately, even extensive laminations may not give rise to any visible abnormality at the surface of the sheet, and BISRA's Physics Department developed a hand-operated lamination detector intended primarily for examining the ends of cold-rolled coils. It makes use of the fact that when a potential difference is applied to two points on opposite sides of a uniform sheet the flow of current is concentrated in a narrow zone surrounding the direct path through the sheet. If, however, a lamination or other discontinuity is present, the current cannot follow the direct path between the contacts but must flow round the obstacle, and the presence of a lamination can thus be detected at the surface by measuring the potential difference between two points close to the current-carrying contacts.

By replacing these two pairs of electrodes by two pairs of silver steel disks on spring-loaded castor mountings, the method can be applied to the continuous examination of cold-rolled steel sheet, and equipment for this purpose is now being manufactured under licence from BISRA by the Ultrasonoscope Co. (London), Ltd. Each disk is indendently sprung to ensure good contact on slightly uneven surfaces. The disks are automatically traversed back and forth across the sheet so as to scan a strip about 6 in. wide. For sheet 3 ft. wide at least six of these units would thus be required. During a complete traverse about 6 ft. of strip passes the contacts; this gives a high probability of detecting a lamination. The castor mountings on which the disks are carried run on ball-bearings and align themselves so that the disk is free to roll and does not slide, which would mark or score the sheet. When tested in a laboratory "mock-up" with strip moving at 300 ft./min. the equipment satisfactorily detected laminations 0·5 in. wide in strip 0·020 in. thick.

Continuous Inspection of Tinplate Surface Quality

Inspection for surface defects on tinplate lines is usually carried out visually "inline," and suspect sheets are rejected for subsequent re-inspection at slower speeds. An instrument shown to visitors to Battersea is being developed to carry out this process more efficiently, with less re-inspection, and to meet further requirements for tabulated data on the surface quality of tinplate in coils.

A high intensity strip lamp illuminates a band 0·1 in. wide across the full width of the moving tinplate. Each 1 in. segment of this illuminated band is viewed by a separate photocell, the viewing angle lying between 5° and 30° to the direction of illumination. Under these viewing conditions prime tinplate gives no output signal, while a defect generates a signal which depends upon the degree of the defect and upon the ratio of its area to the total area of strip viewed by the photocell.

To reduce the electronic equipment required to interpret the signals from the thirty or more photocells, each photocell is sampled in turn, the sampling rate being so chosen that no significant information is lost. The signal from each photocell is assigned to one of four levels, according to severity of defect. Rectangular hysteresis-loop Ferrite cores are used for the dual role of sampling and classifying. The information pulses from all photocells can then be fed to a counting unit for each of the four classification levels.

The next stage in development is to establish the relationship between the pulse count given by the instrument and the acceptability of the tinplate for the various jobs for which it is used; the "acceptability" of the tinplate being solely a matter of judgment by trained personnel. Preliminary work on this problem is in hand.

The Behaviour of Metals under Combined Creep and Fatigue

In addition to instrumentation and automation, the Physics Department's interests includes the study of various aspects of metal physics, including the behaviour of metals under various conditions of stress.

There has been a growing awareness in recent years of the inadequacy of tests and standards which give isolated indices for the mechanical behaviour of metals and alloys. In service, components are subjected to stresses and conditions which may be quite different from the idealised ones in a laboratory test. It is now clear that processes of deformation, fracture, corrosion, etc., do interact in a complex manner and that the overall behaviour cannot be predicted by a simple superposition of test results.

Many examples can be given of components which are subjected to both a static (creep) stress and a cyclic (fatigue) stress. A turbine blade creeps longitudinally under the action of centrifugal force and is subjected to a fatigue stress due to its own lateral vibration. The blade may fail by either creep or fatigue or a combination of the two, depending on the relative severity of the stresses.

In the research programme undertaken by BISRA, the fundamental aspects of the effect of a fatigue stress on the creep characteristics of metals are being investigated, and a commercially available creep testing machine has been modified so as to induce combined creep and fatigue stresses in the specimen. The main conclusions of the work so far, which has been conducted on pure fully annealed lead, copper and zinc are given below.

(1) The introduction of a fatigue stress in a metal subjected to a creep stress generally results in a deterioration of the creep strength of the metal.

(2) As this behaviour was observed in single crystals, it is concluded that the effect of the fatigue stress must lie in the processes inside the individual grains. The contribution of grain boundaries appears to be small.

(3) The transient creep strain in the presence of a fatigue stress was found to follow a $(\text{time})^{\frac{1}{3}}$ law. This is in contrast to the static Andrade law of $(\text{time})^{\frac{1}{2}}$. The $(\text{time})^{\frac{1}{3}}$ law suggests a hardening process during the transient period based on a diffusion process which locks the dislocations. Vacancies are known to be generated by a fatigue stress, and it is likely that they diffuse to the dislocations, causing a decrease in their mobility and a decrease in the creep rate.

(4) The process of creep recovery, namely, the slow return of a plastically deformed metal to its original dimensions when the external stress is removed, was found to increase when a fatigue stress was introduced. This effect was observed both in single crystals and in polycrystalline specimens. The mechanism responsible for the phenomenon is likely to be the slow movement of piled-up dislocations back to their sources under their mutual repulsion when the external stress is removed. The cyclic stress increases the mobility of the dislocations by assisting them in overcoming minor frictional stresses in the slip plane, and by resisting the locking of dislocations by impurity atoms and point defects.

Operational Research Department

Ergonomics

Ergonomics, the study of the relation between man and his working environment, brings anatomy, physiology, and psychology to the service of the engineer. The use of ergonomic principles can shorten the time needed to carry out tasks, improve the health of workmen, and lessen fatigue, making accidents less likely. It frequently shows that fewer men are needed for particular tasks, thus increasing productivity and, by making work easier to perform, shortens the time required for training.

Much of BISRA's work in this field has been on the design of crane cabs and crane controls, chiefly because this work was necessary. The older type of cab is unsatisfactory in several respects: the driver has to stand, the controls are big and awkward to operate, there is no protection from heat, dust or fumes, and it is difficult to see out.

The work of designing new types of cab was carried out in several stages. The first stage consisted of laboratory experiments in which several types of experimental hand and foot controllers were tried out, with the operator being set a task which to some extent simulated that of an actual crane motion; he had to line up a movable pointer under his control with a fixed pointer. The controllers could be set up in various ways and the operator's performance with each of these set-ups was recorded on punched tape. The data was analysed statistically and recommendations made to engineers on the design of controllers for speed and accuracy of

operation. Aspects which have been considered are the "feel," length of handle, number of speed steps and arc of movement of a hand controller: and the position of the pivot, "feel," number of speeds, and arc of movement of a foot controller.

Experiments were next carried out in actual works. Apparatus was fitted to the controllers of cranes in several steelworks to record which controllers were used and the order in which they were used. To ensure that all controllers would be within the operator's reach and that no confusion between levers would occur, trials were made in which operators made adjustments on full size models of the controllers to be used. The results of these two types of trial yielded general information on the placing and layout of controls in any particular control point.

The problem of seating was tackled in collaboration with the Medical Research Council. The seat finally developed is a simpler version of the one designed for the Navy for watch-keeping jobs.

In the final stage of the project the best position and design of a particular crane cab structure were determined on the basis of studies on a model crane and warehouse.

Research is now being sponsored at the Medical Research Council's Unit for Climate and Working Efficiency into the best means of protecting operators from the effects of heat. The emphasis in this investigation is on the repair and rebricking of furnaces, and on de-seaming and the manipulation of hot ingots during forging. The first step in this research is to investigate the temperature conditions prevailing in different situations, and the next to develop suitable screens or protective clothing to enable the operator to perform his job efficiently and without any ill effects. Existing types of protective clothing are often unwieldy and difficult to work in. One special study has also been carried out in this field in which a company which was planning to build a new shop was advised on the best ways to design the shop to reduce the heat load on the men working in it.

Work has been and is being carried out on the design and layout of all types of rolling mill control points, the design of dials and indicators, and the energy expenditure in coupling and uncoupling railway wagons. The section is also co-operating with workers in the Department of Psychology at Reading University who, under a grant from the D.S.I.R., are studying the skills of process operators.

Using an Electronic Computer to Reduce Waste at the Hot Saw in a Rolling Mill

The end product of a rolling mill is steel section, in a variety of cross sections and gauges, cut into lengths as ordered by the customers. The section is rolled from ingots or blooms, and may be anything from 100 ft. to 300 ft. long when it reaches the hot saw. Although this length can be estimated from knowledge of the ingot or bloom weight and the expected weight per foot of the finished section, the estimate would not be sufficiently accurate for a cutting-up schedule to be planned in advance.

At the hot saw, lists of customers' orders are available and it is the responsibility of an operator, known in some mills as the "checker," to select from the orders the lengths to be cut from each main length of section. This entails estimating the length of the finished rolled section; and to help the checker to do this, marks are

Open Day visitors discussing aspects of the work on metal physics.

placed at regular intervals along the roller table. In selecting the lengths to be cut, his main object is to waste as little of the good section as possible, but at the same time not to cut into so many customers' orders that it becomes difficult to sort them on the cooling banks.

Most rolled sections have damaged ends, and thus a certain amount of scrap is inevitably produced. Over and above this the checkers at a number of mills visited were found to waste a further 1–2%: the average amount was 1·55%. This waste may not seem too serious until it is realised that it represents a loss of over £100,000 per year in a mill rolling 5,000 tons per week.

Investigations carried out by the Operational Research Department have shown that it is possible to feed the lists of customers' orders into an electronic computer, so that when the length of the good section available is fed into it by the operator, the machine will select the best combination of lengths to be cut.

The problem of measuring the length of good section to the accuracy required is at present not solved very satisfactorily. The system could work quite well if the length were visually determined from a scale painted on the roller table, but methods for measuring the length automatically and relaying it to the computer are being developed, and when completed should enable the whole procedure to be made independent of manual operation. In a mill equipped with automatic saw-bench length-setting equipment, the setting of the saw mill will be controlled directly from the computer; in other mills, the lengths selected by the computer will be displayed on a screen so that the sawman will be able to cut the lengths computed.

Trials of the selection process have been carried out on the BISRA *Pegasus* computer using actual works data. The wastage was found to average about 0·25% when considering a maximum of five orders at a time. In practice, however, saws do not cut accurately to the nominal length, and tests have shown that a further 0·25% must be allowed to cover against short lengths. Thus, an average saving of about 1% is possible with currently available equipment, so that with two computers (one for use as a standby when the other is being repaired or serviced) the annual saving in a 5,000 tons per week mill would be at least £50,000, even if the computers were depreciated over five years.

Open Hearth Furnace Repairs and Furnace Availability

Profits from an open hearth melting shop depend on a large number of factors. In times of unsatisfied demand output is limited by the furnace rate of production or "driving rate," the life of the furnace between repairs, and the time that a furnace is down for repairs. In the larger melting shops there is a chance that two or more furnaces may be down for repair at the same time, and if the normal incidence of repair only justifies the employment of men and equipment sufficient to repair one furnace at a time, further production time will be lost because of this "bunching."

A great deal can be done to reduce the effects of the limiting factors, often at comparatively little cost. Work at BISRA has been concentrated on investigating the combined effect of all these factors, and suggesting methods by which the maximum profit can be obtained from any particular melting shop.

For example, the hourly tonnage of steel produced by a furnace can be increased by greater heat input and hence greater speed of melting, but the higher temperature usually results in a shorter roof life and therefore more frequent repairs. Thus, to determine the greatest profit-making capacity of a shop it would be necessary as a first approximation to balance the extra cost of fuel and repairs against the improved tonnage. However, the increased number of repairs would increase the chance of two or more furnaces needing repair at once. This danger can be diminished by adopting a repair schedule.

Work on the various methods of scheduling has shown that perfectly "safe" scheduling is generally uneconomic, because furnaces tend to be repaired long before they really need it. On the other hand, a programme based on the longest possible life of a furnace would soon be disrupted. A course somewhere between these two, periodically modified, has been shown to be the best. Further, to overcome tight schedules and to diminish the chance of "bunched" repairs it is often possible in practice to repair a furnace much more quickly than usual, although this increases the cost of repair.

A considerable amount of research has been done in this field, and it has been shown that by proper scheduling worthwhile savings can be made in any size of open hearth shop. Numerous melting shops have been visited and the different repair techniques in use studied, a furnace model set up and the effect of adopting any of these techniques explored, the aim being to achieve the greatest possible profit. It was found that the profit from the extra steel obtained by speeding up a repair must be balanced against the extra cost of the repair: the quickest repair is by no means always the most economic. Of course, if only a specific tonnage is required from a melting shop, the most economic repair technique for this tonnage can be determined.

The more important results of the investigation can be summarised as follows:—

(1) It is essential that repairs should be carried out systematically: i.e., demolition should first be completed in that area in which the maximum amount of bricking needs to be done, and so on.

(2) A balance should be obtained between bricklayers and demolishers, so that one or other group is not unemployed in the middle of the repair.

(3) It is worth having the necessary machinery available, for example, gradalls and shovels, except perhaps in the smallest shops.

(4) Horizontal blasting of slag pockets is generally very profitable.

(5) Hanging centres for roof bricking can save manpower in shops where a gradall is not economic.

These general results and others were obtained from a particular type of furnace, but the methods used are equally applicable to any size of furnace in any size of shop. Actual calculations will clearly depend on the characteristics of individual shops and on management policies. However, it is felt that study and discussion on research methods and results may well assist management in saving many thousands of pounds a year.

Beryllium Tubemaking

Tube Investments, Ltd., announces that its subsidiary, The Chesterfield Tube Co., Ltd., has reached a "know-how" agreement with the Superior Tube Co., of Norristown, U.S.A., on the manufacture of beryllium tubes. As a result of the agreement, the American company will be supplied with the techniques of beryllium tube drawing and finishing developed by the Chesterfield Tube Co. and the TI Research and Development Division, and the future beryllium research programmes of the two companies will be co-ordinated with a full exchange of information. Chesterfield Tube now holds a world lead in the production of precision tubes in beryllium.

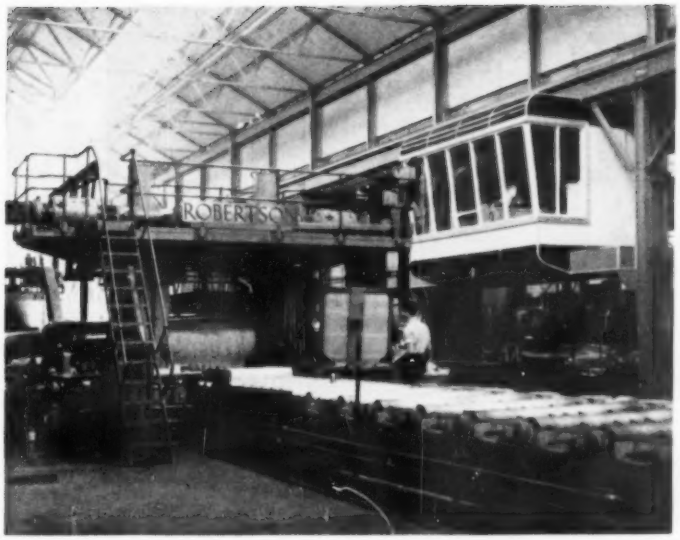
The unusual metallurgical properties of beryllium make it one of the most difficult to process, but it has attractive qualities for nuclear reactor fuel cans and other high duty engineering applications. Chesterfield Tube has already received contracts for beryllium precision tubes worth around £250,000 from the United Kingdom Atomic Energy Authority and from America and France; one order recently completed was for fifty small bore tubes 5 ft. long.

Purchasing Officers' Course

The third Oxford course of the Purchasing Officers' Association includes for the first time material study groups (in co-operation with the British Iron and Steel Federation and the British Non-Ferrous Metals Federation) and an operations research study group. In addition to an address by Professor R. W. Revans, Professor of Industrial Administration, Manchester College of Science and Technology, on "The Meaning of Administration," there will also be a panel discussion on "The Effect on Buying Policy and Practice of Current Restrictive Practices Legislation" between R. L. Sich, C.B.E., Registrar of Restrictive Trading Agreements, A. H. Thomas, President of Purchasing Officers' Association, and a spokesman from industry. The Course will be held at Christ Church and Pembroke College, Oxford, from March 21st to 25th, 1960, and the fee for full-time attendance will be £25 per person. Although the Course is primarily intended for those holding senior purchasing appointments in industrial and public undertakings, other functional executives will be welcome to attend. A full programme may be obtained from the Secretary, Purchasing Officers' Association, Wardrobe Court, 146a Queen Victoria Street, London, E.C.4.

Aluminium Sheet Production in North Wales

Aluminium Corporation's Golden Jubilee



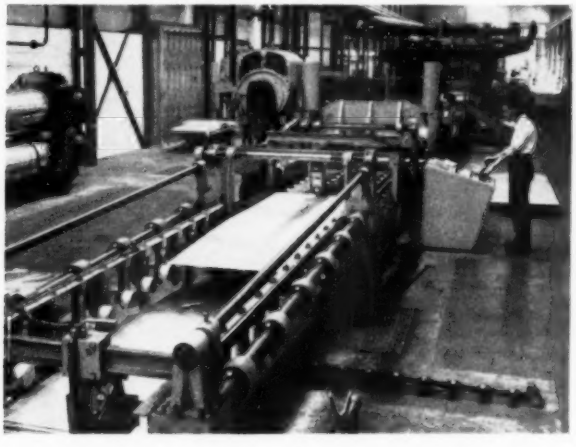
The 28 × 60 in. 2-high hot reversing mill showing the control pulpit.

THE first production of aluminium from local hydro-electric power at Dolgarrog, in the Conway Valley, dates back to 1908, but it was not until December, 1909, that the present Aluminium Corporation, Ltd., was formed. The early years, during which the hydro-electric scheme was being developed, were a hard struggle for the company due to shortage of capital and the low price of aluminium.

Just prior to World War I, most of the aluminium produced at Dolgarrog and surplus carbon anodes were sold to Germany, from which country alumina was purchased. During the war Dolgarrog became a controlled establishment, and a small rolling plant was set up in 1916, so that the Corporation became rollers of their own metal with the modest production capacity of 3–4 tons per week.

After the war the company's financial position showed some improvement and a development programme was put in hand which included additions to the rolling mill and furnace room and the building of a further hundred houses for employees in Dolgarrog village. This programme suffered a severe setback when in 1925 the dam on Llyn Eigiau burst, causing the loss of sixteen lives and burying the works in six feet of debris.

In 1926 the Corporation became associated with a new company known as the International Aluminium Co., Ltd., and its Norwegian subsidiary, A/S Haugvik Smelteverk, from whom ingot metal for rolling was purchased at a favourable price. Three years later it became necessary to dispose of the hydro-electric plant to the North Wales Power Company, who agreed to supply power at a special rate for a period of twenty years. Further additions were then made to the rolling plant, raising the capacity to 3,000 tons per annum. In 1931 the Alliance Aluminium Compagnie, an international company formed to control production of aluminium in Europe, obtained a majority of the shares in the Corporation.

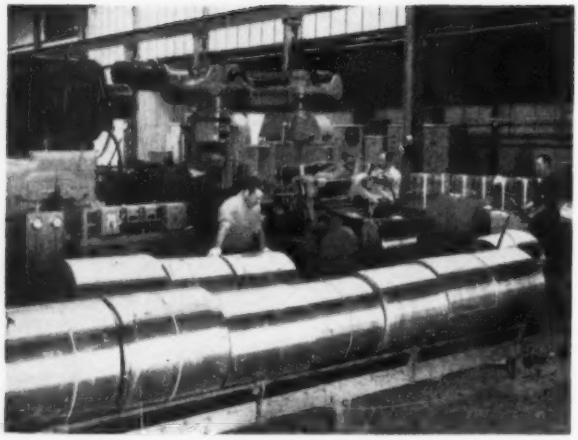


Automatic piler operating on hot rolled sheet blank.

During World War II Dolgarrog was working round the clock, mainly producing sheet for aircraft, and at this stage the annual output rose to over 5,000 tons. By 1944 large supplies of Canadian ingot metal were available, so the furnace room was closed down due to the very high cost of power, and production of ingot ceased.

In 1949 The British Aluminium Co., Ltd., took over Alliance Aluminium Compagnie's holding in the Corporation, and immediately started to modernise and improve the rolling mills and village properties.

The latest development started three years ago when it was decided to replace the old 3-high hot breaking down mill, which was the limiting factor to output, with a modern 2-high reversing hot mill equipped with up-to-date handling facilities and coiling equipment. When full capacity working is reached, the mill will be producing up to 5 tons per hour of hot rolled slabs. The new hot mill has brought semi-automation to Dolgarrog and has opened the way for future development and increased employment.



Coil conveyor transport to entry side of 2-high cold strip roughing mill.

Dalgarrog Today

Production at Dolgarrog is mainly commercially pure aluminium, aluminium-1¼% manganese alloy, and aluminium-magnesium alloy in sheets, blank circles and coiled and flat strip. Ingot is obtained from Kinlochleven in Scotland and Baie Comeau in Canada. Furnaces of 8 and 10 ton capacity, used to melt charges comprising virgin metal and scrap arising in the works, are oil-fired and incorporate preheat chambers in which the waste gases are used. Molten metal from these furnaces passes by launder or by ladle to 5–6 ton holding furnaces from which it is tapped into ladles for casting into billets after degassing. The metal is cast into water-cooled cast iron moulds which are tilted hydraulically, the angle of tilt changing as casting proceeds. The mould is "topped-up" during solidification and when completely solid the billet is ejected from below by a hydraulic ram. In addition to the melting furnaces reffered to above, there is a 1 ton oil-fired semi-rotary furnace for making hardener alloys.

Billets may go straight from the chills to the hot mill, or they may be charged into a Dowson and Mason reheating furnace capable of holding 20 tons of billets loaded flat in stacks of three in two banks. The new Robertson mill is a 28 in. × 60 in. reversing mill giving a rolling speed up to 350 ft./min., and having run-out tables at both sides, with hydraulic manipulators for handling the ingoing material. The products of the mill, which will roll billets up to 1,000 lb. in weight, are strip blank 15–52 in. wide and blank for sheet rolling, the two classes of product leaving the mill at opposite sides.

The top roll and top spindle drive are hydraulically balanced, and the totally enclosed fabric bearings are lubricated by soluble oil. The two separate D.C. screw-down motors are coupled by an electro-magnetic clutch which can be disengaged for individual screw adjustments. Orthodox dial gauges are provided, together with Selsyn indicators to show the roll opening in the control pulpit, where the controls include remote control of soluble oil roll body coolant from banks of sprays: automatic change-over of the sprays takes place with the directional change of the rolls. Hydraulically-operated walking-cylinder type roll change equipment is provided.

The Metal Industries Division of English Electric Co., Ltd., was responsible for the major part of the electrical equipment for the new mill. The main drive is an 800 h.p. D.C. motor with a speed range of 150–300 r.p.m., fed from an Ilgner set consisting of a 1,000 h.p. A.C. motor running at 985 r.p.m. and a 670 kW. D.C. generator. The electrical bay is atmosphere conditioned by filtered air entering through ducting and venting through louvres—to the outside in summer and into the mill bay in winter.

Drives for the run-out tables are below floor level, and as was mentioned earlier the sheet blank and strip blank leave the mill in opposite directions. At the end of one run-out table there is a heavy duty up-cut shear, conveyor and piler for handling the sheet blank, and the other table leads to a shear for end cropping or halving, to edge trimming and/or slitting equipment, and thence to a coiler capable of handling material up to 52 in. wide.

Inclined conveyors feed coils to the range of cold rolling mills, where the material is reduced to the required thickness and given the requisite hardness and surface finish: sheet blank is finished in a further series of mills. Much of the output of the works ends up as hollow-ware, and in order to meet the varied requirements of customers with regard to size and shape of blanks required, an extensive range of shearing and blanking equipment is available. Heat treatment plant for inter-stage annealing and final heat treatment where necessary include Efco salt baths and annealing furnaces, and a flash annealing furnace for circles.

There is a strong community spirit at Dolgarrog. Most of the houses in the village are owned by the company and occupied by employees. Many people in the village have worked for the company for a long time, some since its very earliest days, and there are about 100 members of the Thirty Year Club. The factory itself occupies 211,000 sq. ft. of floor space on a 26 acre site and is laid out to blend with the character of the Conway valley. Excellent canteen facilities are provided within the works; also a well equipped first aid room and ambulance, and fire brigade services manned by trained employees.

Dolgarrog rolled products are widely known for high quality, and the continuing development of these works will enable the company to take full advantage of the world-wide increase in the demand for aluminium. T.I./Reynolds having acquired control of the British Aluminium Group, of which Aluminium Corporation, Ltd., is an independent subsidiary, will no doubt encourage the realisation of these aims.

B.W.R.A. Move

THE London Office of B.W.R.A. is now at 19 Fitzroy Square, London, W.1. Telephone: EUSton 9595/6; Telegrams: Weldaserch, Wesdo, London. The London office will house the committee meeting room, the membership and liaison staff, and secretarial and accounts staff. All invoices and remittances against invoices should be sent to the above address. The research sections, research committee secretariat, design advisory service, library and publications section are at Abington Hall, Abington, Cambridge. Telephone: Linton 375 and 388. Requests for library loans, and orders or enquiries for publications, should be addressed to Abington Hall.

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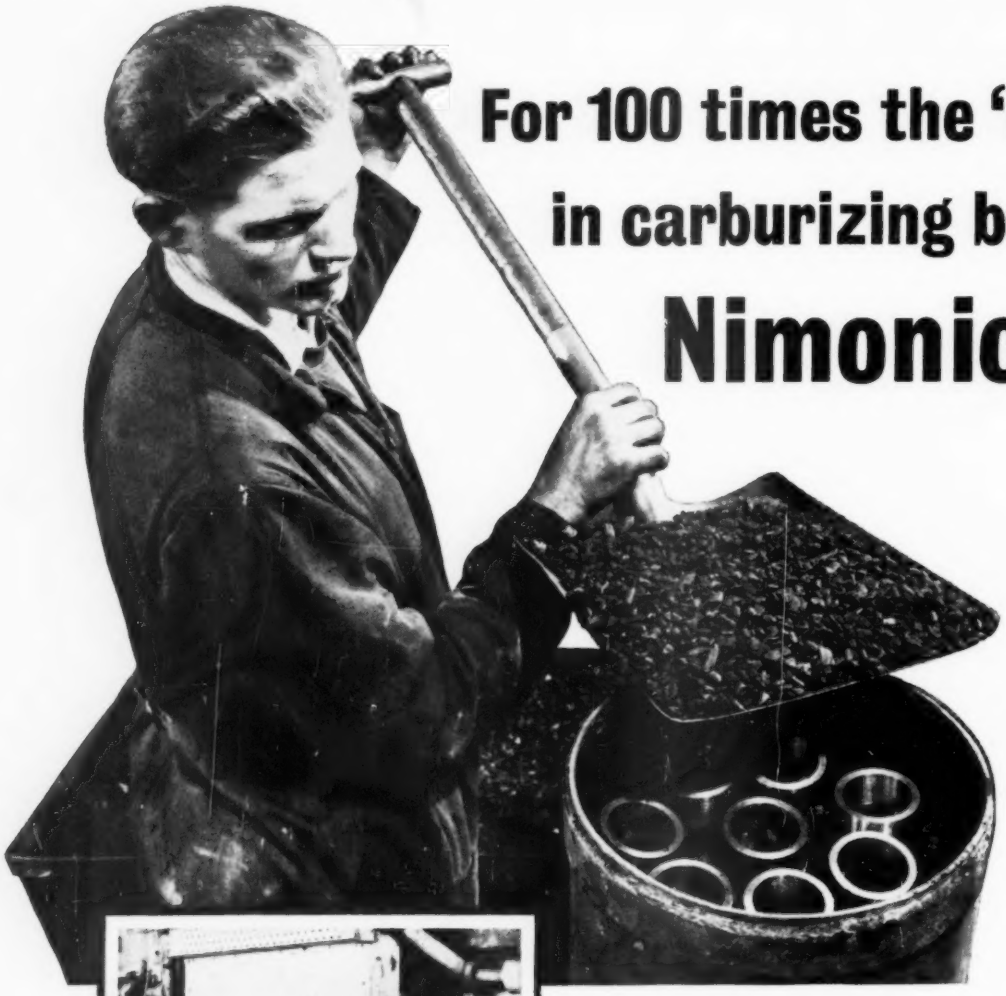

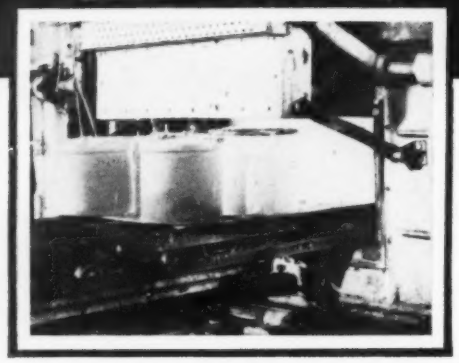

David Brown Industries Limited have found that carburizing boxes of Nimonic 75 heat-resisting alloy outlast mild steel no less than 100 times. The boxes are still in good condition after 8,000 hours of service without repair. Carburizing temperatures range from 900° to 915° C, and treatment time is approximately 18 hours. This nickel-chromium-alloy has also far outlasted all other materials used.

Nimonic 75 is easily shaped and welded. Because of its strength at elevated temperatures, thinner sections can be used, permitting greater loads, less furnace time, easier handling and a longer service life.

TOP

Charging a carburizing box made from wrought Nimonic 75 alloy. In the 'pack carburizing' of a wide variety of gears, David Brown Industries use this material increasingly for its ease of fabrication, resistance to heat and superior 'life'.

INSET

A Nimonic 75 carburizing box being withdrawn from a furnace. The alloy gives exceptional resistance to oxidation and useful mechanical strength at very high temperatures. It is widely used in industry for countless other high-temperature problems.

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NEWS AND ANNOUNCEMENTS

Gas in Industry Exhibition

An exhibition illustrating "Gas At Work In Industry" will be held at the Royal Horticultural Hall, Westminster, from March 1st to 12th, 1960. It will be the second of its kind, the first having been staged in 1957, and proving so successful that there have been many requests for another on similar lines. As in 1957, the exhibition is sponsored by four of the Area Gas Boards—Eastern, North Thames, South Eastern and Southern.

How gas continues to meet the demands of modern industry will be demonstrated by working plants, models, photographs, films, etc. There will be demonstrations of metal melting, tinning, die casting, and special purpose plant for the clean heat treatment of metals. Another feature will be the vitreous enamelling of aluminium, of special interest as it will employ plant of new design. Drying operations by means of direct and indirect plant will be seen, and an infra red plant will carry out paint finishing operations.

Symposium on Fatigue of Welded Structures

The British Welding Research Association and the Engineering Department, Cambridge University, are jointly organising a symposium under this title. This is to be held in the Engineering Department, Cambridge University, from Tuesday, March 29th, until Friday, April 1st, 1960. A full discussion of the subject of fatigue of welded structures is thought to be of considerable importance at the present time. A good deal of research has now been carried out, but the expansion of welding fabrication in many areas where fatigue strength is a criterion is revealing new aspects of the problem. Present knowledge might therefore be usefully consolidated and new aspects considered by those people who are directly concerned with and interested in the investigation of the fatigue of welded structures. Several papers will be presented, and these will include contributions from the United States and from East Germany. They will deal primarily with structures fabricated by fusion welding processes. The fee for membership of the symposium is 15 guineas. Further particulars may be obtained from the British Welding Research Association, Abington Hall, Abington, Cambs.

Machine Tool Research and Education

The Machine Tool Trades Association and the Department of Scientific and Industrial Research are continuing their discussions of the action to be taken as a result of the D.S.I.R. survey of the research and development requirements of the British machine tool industry. A further meeting was held on December 8th, 1959, at which representatives of the Ministry of Education were also present. The meeting was concerned with two major subjects, education and research.

On education, the representatives of the industry concurred in the view of the Ministry of Education that the existing education and training facilities for students proceeding beyond Higher National Certificate level could be more fully used, but that more specialised courses were also necessary. There was a need for both more students and more teachers. The representatives of the Ministry of Education invited the industry to assist in reviewing the curricula of existing courses and in devising any necessary new courses.

On research, the meeting noted that D.S.I.R. grants for research in the field of machine tool technology had already been made to two universities, and that others were under consideration. It was also noted that exchanges of visits between research engineers from the National Engineering Laboratory and engineers from machine tool firms had taken place. More were being planned. While appreciating the advantages of making more use of existing facilities for research, the representatives of the industry undertook to give further consideration to the type of research organisation most suitable to the needs of the industry. It was agreed that there was a need for much closer co-operation between engineers and designers in industry, on the one hand, and the research work of universities, colleges and research institutions on the other.

Discussions will continue in further meetings on specific aspects of the problems involved (education, research, design). A further announcement will be made when a co-ordinated plan has been agreed.

Repeat Induction Heating Course

Due to the large number of applications for attendance at the first Pye Induction Heating Course which was held at the beginning of December, it was impossible to accommodate all who were interested. The Process Heating Division have therefore decided to hold another course commencing at 2 p.m. on Tuesday, 1st March, 1960, and finishing at 6 p.m. on Wednesday, 2nd March, 1960. This will cover the same subjects as in the first course, namely the theory of induction heating; how the generator works; and the design of coils for hardening, annealing, tempering, brazing and soft soldering; but due to the obvious interest there will be more accent on applications. As before, the course is free, but members attending have to pay their own living accommodation, which is normally arranged by the company. Further details of the course may be had from Mrs. E. Raeburn, Pye Process Heating, 28 James Street, Cambridge.

New Fox Stainless Plant

Work on schemes totalling £2 million to expand the production capacity for stainless steel is being undertaken by Samuel Fox & Co., Ltd., a subsidiary of The United Steel Cos., Ltd. Pioneers of large arc furnaces in this country, Samuel Fox are regularly making stainless in their 70- and 80-ton furnaces, and production at Stocksbridge is now over 1,000 tons a week. The rapid and steady growth in demand for stainless steel flat products has necessitated further expansion of rolling capacity. Recently, Samuel Fox announced a £1 million project to modernise their Stocksbridge hot mill which, by the middle of 1960, will enable them to produce sheets and plates up to $\frac{3}{4}$ in. thick and 6 ft. wide.

The cold mill is already capable of rolling 6 ft. wide sheets as the result of a carefully planned engineering operation during the summer. In the two weeks when production stopped for the works' summer holiday, this mill was completely rebuilt and widened from 42 in. to

84 in. This was made possible by carrying out preparatory work, such as foundations, over a period of many weeks beforehand, with as little disturbance to production as possible, leaving the final moves to be concentrated into the holiday period. Now, work is to begin shortly on a scheme at Shepcote Lane Rolling Mills, Ltd., in which Samuel Fox have a one-third interest, to expand the production of wide stainless steel coils from 450 to 800 tons per week. The main additions to the plant will consist of a second 42 in. Sendzimir cold rolling mill and a fourth softening and descaling line, together with extensions and modifications to existing ancillary plant, as well as the installation of an extra coil build-up line and a new furnace for softening ferritic steels.

These plans will be welcomed by the many users of stainless steel. Two of the leading outlets for stainless steel sheet and strip are domestic sinks and motor car trim, and the output of both of these products is expanding at an unprecedented rate. Stainless steel is also finding many new applications, and manufacturers of domestic cooking utensils, washing machines and many other kinds of household equipment are progressively turning over to it to meet the needs of modern living standards.

Pergamon Press Move

PERGAMON PRESS, the international scientific publishing house, is moving some of its editorial, publicity, journal and book production departments from its London headquarters in Fitzroy Square to Headington Hill Hall, Oxford. The lease of Headington Hill Hall was offered by the Oxford City Council when the firm's London warehouse premises were compulsorily requisitioned by the L.C.C. under their Elephant and Castle redevelopment scheme. Also moving to Headington Hill Hall is an associated company, I. R. Maxwell & Co., international, university and industrial booksellers, and the Pergamon Institute, a non-profit foundation formed in Washington, D.C. in 1957 for the purpose of making available to English-speaking scientists, doctors and engineers (from all countries that are members of the United Nations), the results of scientific, technological and medical research and development in the Soviet Union and other countries in the Soviet orbit.

Metal Physics Lecture

DR. W. C. WINEGARD (Associate Professor of Metallurgy in the University of Toronto) has accepted an invitation from the Metal Physics Committee of the Institute of Metals to lecture on "Solidification of Alloys." The lecture will be given at 6.30 p.m. on Wednesday, 10th February, 1960, at the Institute's Headquarters, 17 Belgrave Square, London, S.W.1. Visitors will be welcome, no tickets are required.

Fischer Bearings Acquired

THE TIMKEN ROLLER BEARING COMPANY and The Fafnir Bearing Company of New Britain, Connecticut, U.S.A., have announced that an agreement will shortly be concluded by which a recently formed subsidiary of the latter, Fafnir Bearing Co., Ltd., will purchase the business of Fischer Bearings Co., Ltd., a Timken subsidiary. The sale of Fischer, which was until recently owned by the former British Timken, Ltd., results from the Timken decision to confine their interest to the manufacture of tapered roller bearings throughout the world. They will, however, continue for the present to distribute F.B.C. bearings for replacement purposes in Britain, through their subsidiary Timken stockists, and in Australia, South Africa and Canada, through their branches in those countries. It is intended that Fafnir's British products will be marketed under the Fafnir name, and that the business will be expanded to meet the anticipated increase in demand in both British and world markets, and in particular the overseas factories of Fafnir's American customers.

Long Service at Loxley

THERE must be considerable satisfaction in being presented by the firm you direct with a long service award. Mr. Arthur Marshall, managing director of Thomas Marshall & Co. (Loxley), Ltd., refractory manufacturers, received from Mr. Thomas Marshall, chairman of the company, a gold watch in appreciation of his forty years' service. With him in a photo finish was Mr. C. W. Marsden, another director of the company. The occasion was the Works Party at Cutlers Hall, Sheffield, on December 29th, when, as well as the two directors, nine senior members of the firm received twenty-five-year awards.

The company introduced long-service awards in 1942, since when eight have been made for forty years, and sixty-three for twenty-five years service. Four local families, Furness, Helliwell, Harper and Robinson, have counted almost two centuries' service each with Thos. Marshall.

The Institute of Metals

THE Prime Minister (The Right Hon. Harold Macmillan, M.P.) has accepted an invitation to be the principal guest and speaker at the Annual Dinner of the Institute of Metals, which is to be held in the Great Room, Grosvenor House, London, W.1., on 31st March, 1960. The United States Ambassador has accepted to reply to the toast of "The Guests."

First Sillimanite-Lined Blast Furnace

AT Appleby-Frodingham Steel Company, Scunthorpe, on Monday, 21st December 1959, Mr. A. Bridge, Ironworks Engineer, lit Queen Mary furnace, the first blast furnace to have a complete sillimanite stack lining. The lining was supplied by General Refractories, Ltd., in Sillmax "I" quality, which is a bondless brick manufactured from 100% natural sillimanite of the highest purity. The excellent physical properties of this refractory include high density; low porosity; high resistance to abrasion and spalling; volume stability at all temperatures likely to be encountered in the lower stack; and high resistance to molten slag, metal, and alkali vapour. The results attained by this lining will be of great interest to iron makers throughout the world.

German Tin Conference

THE technological and economic development of the German tinplate industry was praised by Dr. W. E. Hoare, assistant director of the Tin Research Institute, Greenford, Middlesex, at the Sixth Annual German Tin Conference at Dusseldorf in December. In his opening lecture to the conference, organised by the Zinn-

Informationsburo, Dusseldorf, in collaboration with the Tin Research Institute, Dr. Hoare referred to a number of notable German tinplate plants and said they were operating with commendable success. His paper dealt with the electrodeposition process in the manufacture of tinplate. Among other speakers was Mr. S. C. Britton, head of the electrochemistry and corrosion department at the Tin Research Institute, who gave a progress report on a process for the electrodeposition of bright tin, developed by the Institute two years ago and now in commercial use. Chairman at the conference was Professor Dr. E. Raub, director of the Forschungsinstitut fur Edelmetalle und Metallchemie at Schwabisch Gmünd.

Hot Strip Mill Order

THE order for the building of the 68 in. wide hot strip mill for the new Spencer Works at Newport, Mon., of Richard Thomas & Baldwins, Ltd., has been placed with Davy and United Engineering Co., Ltd., of Sheffield: the value of the contract exceeds £4 million. The new mill will go into production in October, 1961, and will have an initial output of about a million tons of steel strip a year. It is, however, being designed to provide for an eventual output of around three million tons a year. Davy-United will be collaborating on the project in conjunction with their American associates, United Engineering & Foundry Co., of Pittsburgh, who will be building the slabbing mill and most of the cold rolling plant required for the Spencer Works. It will be recalled that Colvilles, Ltd., recently ordered from Davy-United the new 68 in. wide hot strip mill for their Ravenscraig project in Scotland.

Personal News

Metropolitan-Vickers Electrical Co., Ltd., announce the appointment of MR. J. D. BUCHAN as assistant manager, publicity department.

THE following appointments have been made in respect of wholly owned subsidiary companies of English Steel Corporation, Ltd.: MR. W. D. PUGH to the office of chairman of English Steel Forge and Engineering Corporation, Ltd., English Steel Rolling Mills Corporation, Ltd., English Steel Castings Corporation, Ltd., English Steel Spring Corporation, Ltd., and Taylor Bros. & Co., Ltd.; MR. W. E. A. REDFERN to the office of managing director of English Steel Forge and Engineering Corporation, Ltd.; MR. R. G. H. TAYLOR to the office of chairman of English Steel Export Corporation, Ltd.; and MR. G. CRAVEN, D.S.C., to the office of managing director of English Steel Export Corporation, Ltd.

THE Alloys Division of Union Carbide, Ltd., announce the following executive appointments within their sales organisation: MR. C. DUNGER, previously area sales manager—Sheffield, is now assistant sales manager; MR. W. SMITH, who has been the company's technical sales representative in Scotland for some time, is appointed area sales manager—Scotland (Office: 266 Clyde Street, Glasgow, C.1); and MR. W. PATON has transferred from the Division's development department to take charge of the sales department's Birmingham area, and is now area sales manager—Birmingham (Office: Beaufort House, 92 Newhall Street, Birmingham, 1).

CONSEQUENT upon the recent death of MR. R. B. DAKIN, deputy chairman and joint managing director of Messrs. Walter Somers, Ltd., MR. WALTER SOMERS has been appointed deputy chairman and joint managing director, and MR. A. C. SOMERS has been appointed sales director. COL. T. V. SOMERS, O.B.E., has been appointed production director, and MR. D. C. TYSON, until now in charge of the light forge, has been appointed assistant to Col. Somers. MR. W. M. GRAINGER, secretary, and MR. D. D. CARRINGTON, engineer, have both been appointed to the board of directors.

MR. R. F. SUMMERS (chairman, John Summers and Sons, Ltd.) has succeeded MR. LEWIS CHAPMAN, C.B.E. (chairman, Jessop-Saville, Ltd.) as president of the British Iron and Steel Federation. At a recent meeting of the council of the Federation MR. C. R. WHEELER, C.B.E. (Chairman, Guest Keen Iron and Steel Co., Ltd.) was appointed president-elect for 1960.

MR. H. B. GRAINGER, has been appointed technical manager of Imperial Aluminium Co., Ltd., Waunarlwydd Works, Swansea. He was formerly head of the aluminium section of the research department of Imperial Chemical Industries' Metals Division, Birmingham.

SIR OWEN WANSBROUGH-JONES, K.B.E., C.B., has been appointed a director of The British Oxygen Co., Ltd.

THE Hadfields group of companies, announce that, at his own request, MR. T. H. ARNOLD, M.B.E. has relinquished his appointments as local director and controller of the research department, and also as a director of the subsidiary companies, Hadfields Steels, Ltd., and Hadfields Forgings, Ltd. The chairman and directors of the parent company have accepted his request and also his offer to continue to serve the company as required. MR. ARNOLD is succeeded as local director and controller, research department, by DR. L. G. FINCH, and MR. J. A. GRAINGER has been appointed deputy research controller.

MR. E. T. JUDGE, who was appointed assistant managing director of Dorman Long (Steel), Ltd., a year ago, has now been appointed joint managing director. Mr. Judge has also been appointed an executive director of the parent company, Dorman Long & Co., Ltd.

MR. E. WEISS, managing director of Foundry Services International, Ltd., has been appointed chairman of the company, and MR. A. O. GRUNDBERG, formerly managing director of Sandvik Swedish Steels, Ltd., of Halesowen, Birmingham, has been appointed deputy managing director. MR. P. D. NORMAN has been appointed a director of Foundry Services, Ltd., where he now holds the position of works manager.

MR. H. KERR, director-in-charge of the operating department of Woodall-Duckham Construction Co., Ltd., retired on the 31st December, 1959 and has resigned from the board of the company. Mr. Kerr joined the company in 1929 and throughout his service has been associated with plant operation. He held the position of head of the operating department for the past twenty years and joined the board in 1949.

THE INCANDESCENT HEAT CO., LTD., have supplied capital goods to India for almost half a century, and throughout this period the company has been represented by A.B.M.T.M. (India) Ltd., the manager of which, MR. J. S. HALBERT, is well known throughout Indian industry. Incandescent Heat are now seconding MR. B. A. HARPER

to the staff of A.B.M.T.M. (India), Ltd., where he will be senior furnace technician (India), and will bring to the company a specialised knowledge based on his ten years' experience in the foundry plant division, development the division, and the export division, where he was engaged on technical sales to the Indian market.

THE board of directors of the (American) National Association of Corrosion Engineers has announced that the Frank Newman Speller Award for 1959 has been bestowed on DR. J. C. HUDSON, head of the British Iron and Steel Research Association's corrosion section. The award is made annually in recognition of public contributions to corrosion engineering, and is a signal recognition of distinguished services to this branch of science.

EDGAR ALLEN & CO., LTD., have announced the reconstitution of the boards of four subsidiary companies in the United Kingdom, as follows. British "Rema" Manufacturing Co., Ltd. Sheffield: BRIGADIER A. LEVESLEY, MR. W. J. MCBRIDE, MR. J. P. LEWIS, MR. W. G. A. JENKINS, and MR. J. HIGGINBOTHAM; Buell (1952), Ltd., London: MR. W. J. MCBRIDE, BRIGADIER A. LEVESLEY, MR. O. MARGETSON, MR. G. B. TYLER, MR. M. G. HILL, and MR. F. A. ROSS; J. H. Humphreys & Sons, Ltd., Oldham: BRIGADIER A. LEVESLEY, DR. E. GREGORY, MR. A. HUMPHREYS, MR. G. W. TURTON, MR. F. HAIGH, and MR. W. C. GARRISON; and Park View Steel Works, Ltd., Sheffield: DR. E. GREGORY, MR. A. H. BAXTER, MR. F. HAIGH, MR. G. C. LONGDEN, MR. W. H. EVERARD, MR. L. F. KEELEY. MR. F. A. ROSS will retain the secretaryship of each of these companies, with the exception of Buell (1952), Ltd., where MR. D. F. TIPLADY has been appointed secretary. Recent appointments in Edgar Allen & Co., Ltd., include MR. F. HAIGH as deputy general sales manager; MR. L. F. KEELEY as general manager and MR. R. E. SHERWOOD as deputy general manager of the steel department; and MR. R. GABBERTAS as head of the operational research department.

DR. W. G. HISCOCK, has been appointed chairman of the Lead Development Association for 1960.

THE directors of Ambrose Shardlow & Co., Ltd., have announced that MR. F. A. PERKINS, who is a director of the company, has been appointed chairman of the board, and that MR. J. C. PROUDFOOT has been appointed managing director.

MR. D. N. STEELEY has been appointed sales manager of standard industrial motors at the G.E.C. Engineering Works, Birmingham.

ASSOCIATED ELECTRICAL INDUSTRIES, LTD., have appointed MR. S. WHITE as their chief press officer. He has now taken up his post in the central information department to co-ordinate the press side of the manifold activities of the largest electrical manufacturing group in Great Britain. Mr. White was for five years chief press officer to the United Kingdom Atomic Energy Authority.

Obituary

WE regret to record the deaths of the following:

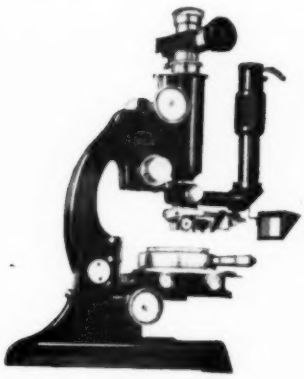
MR. W. H. SPURR, an esteemed and respected colleague, who died at his home in Mellor on December 22nd, 1959, in his 84th year. At the time of his death, he was chairman of Emmott and Co., Ltd., publishers of *Mechanical World* and *Textile Manufacturer*, and of Kennedy Press, Ltd., publishers of *Metallurgia*, which was acquired by Emmott and Co. in 1942. An outstanding record of service—more than 60 years—coupled with a remarkable memory gave him a unique knowledge of the fluctuations of the firm's fortunes from its early days—a knowledge which was invaluable to him when he assumed control. Mr. Spurr joined Emmott and Co. as assistant secretary under the founder, the late W. T. Emmott, and later served successively as secretary, manager and managing director, eventually becoming permanent director and chairman. It was largely due to his hard work, foresight and tenacity of purpose that the company and its journals were built up, soundly based and known throughout the world. A man with definite ideas and ideals of his own, he nevertheless readily appreciated those of others, and encouraged initiative in his younger associates both in business and in private life. Well-read and with a keen interest in art, literature and the countryside, Mr. Spurr was a notable raconteur. His genial personality and gentle disposition made him many friends by whom he will be greatly missed.

MR. W. BRINDLE, who died in a nursing home in Blackpool on January 2nd, 1960, at the age of 75. A native of East Lancashire, Mr. Brindle was, in his younger days, associated with the textile industry and spent a good many years in India between the wars. The last 14 years of his working life—until his retirement in 1951—were spent as advertisement representative for *Metallurgia* in the Midlands, the North of England and Scotland, where he built up a considerable amount of goodwill towards the journal. His genial and friendly disposition endeared him to all with whom he came into contact, as evidenced by the numerous enquiries made about him since he retired, and his passing will be mourned by a wide circle of friends.

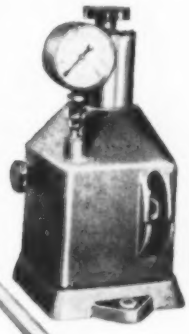
MR. D. J. O. BRANDT, editor of *Metal Treatment* and metallurgical editor of *Iron and Coal Trades Review*, who died on November 23rd, 1959, after a long and painful illness. He was well-known at home and abroad as an authoritive writer, lecturer and broadcaster, and his book "The Manufacture of Iron and Steel" was recognised as a standard work. Born in 1919, Mr. Brandt was educated at Clifton and the Royal School of Mines. After a time with Murex, Ltd., he joined the department of tank design at the Ministry of Supply in 1942 to work on the development and testing of armour plate. After the war he was with John Miles and Partners (London), Ltd., until 1948, when he joined the British Iron and Steel Research Association as a senior scientific officer in the steelmaking division. He left B.I.S.R.A. in 1955 to practice independently as a metallurgical consultant, being largely concerned with the application of oxygen to steelmaking, a subject very near to his heart. At the beginning of 1957 he joined Industrial Newspapers, Ltd., where he continued to express himself in a forthright manner on many aspects of the steel industry, particularly the oxygen steelmaking processes. Of his sincerity and integrity there was no doubt in the minds of even those who disagreed with him. By the untimely death of Oscar Brandt, the steel industry has lost a constructive critic and technical journalists a knowledgeable friend.

MR. T. S. GOULDING, an engineer on the design staff of John Miles and Partners (London), Ltd., consulting engineers, died suddenly from a heart attack at Dublin Airport on December 19th, 1959, on his return journey from Irish Steel Holdings, Ltd. He was 48 years-of-age and had been with the company since 1946.

Micro Hardness Tester



Electrolytic Polisher



BNF
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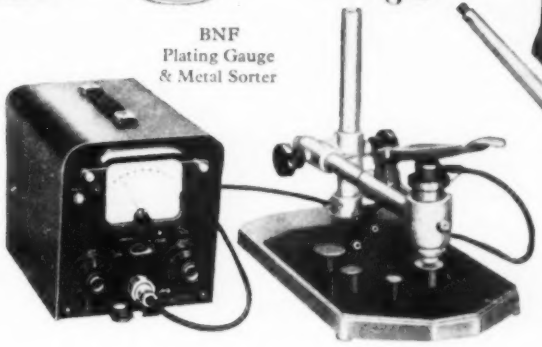
& Metal Sorter



Specimen
Mounting Press

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Light-Sensitive Cells

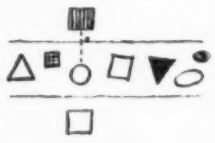
What are light-sensitive cells? They are devices which can sense and measure changes in the level of light or, in some cases, respond to the quality of light falling on them. There are various types of cell and each has its particular field of use. One of the best known is the photo-electric cell.

What can light-sensitive cells do? A change in the amount of light falling on the cell can cause a switch, relay or counter to operate. Alternatively, the direct indication of the light intensity can often allow some other factor to be determined and, if required, controlled. They are reliable and require little maintenance. Careful installation, as with all types of equipment, gives a good reward.

How can they be used? These cells have many applications in industry, for controlling processes, for inspection and measurement, for sorting material and for safety purposes:

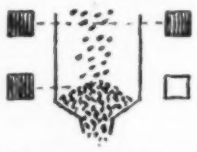
Counting

Where objects on a conveyor belt are too soft or light to operate a direct mechanical counting device, where they are too delicate or freshly painted to sustain physical contact or where the articles vary in size, a light-sensitive cell can be used. This counts the objects by interruption of an appropriately sited beam of light.



Hopper or Tank Level Control

Many forms of feed can be accurately controlled by light cells. One important one is for controlling the input to a hopper of fluid solids such as sand or peas. Here, two horizontal light beams are required: the upper, when interrupted, indicates that the hopper is full and stops the supply; the lower, when it ceases to be interrupted, indicates that the hopper is nearly empty and restarts the flow.



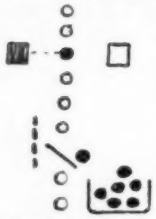
Package Content

The level of powder in packages can be checked with light cells. The cell is so positioned that when the

powder is up to the required level, the light reflected from the surface of the powder is picked up by the cell and causes the carton to be accepted. If not, it is rejected.

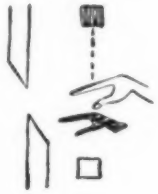
Colour Sorting

The quality of many articles can be gauged by their colour—seeds and nut kernels, for instance. The objects are fed into a tube by means of a vibrator pan and fall into the beams of three equally spaced light cells which scan them from all sides. If the object is acceptable it falls into a chute carrying it to one conveyor; if its colour is bad it is deflected as a reject.



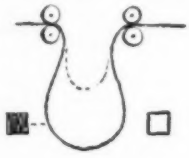
Guillotine Guard

Light cells for guarding a guillotine or power press should be used only as a supplement to a mechanical guard or where the latter is impracticable. The interruption of a curtain of light by a hand stops the machine instantaneously.



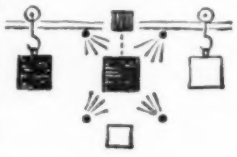
Press Feeding

Where the rate of feed of strip metal must be suited to a varying speed of acceptance by a press, a loop of the strip is allowed to sag between the feed and the press. When the loop reaches a predetermined depth a light beam is interrupted and the slack is taken up.



Processing Objects on the Move

Many articles are processed while on a conveyor line. For instance, where articles are to be sprayed while on the conveyor, the paint saved by stopping the gun between articles will make the device worthwhile. The same principle applies in a bakery to the spraying of baking tins with fat.



Automatic Door Opening and Closing

Doors can be caused to open or close by the interruption of a beam of light. This has its uses in such cases as control of doors on a heating oven or for the passage of vehicles in a factory. This is effected by a light beam on the side from which the approach is made (in many cases, both). When the approach beam is interrupted it opens the door which closes again after a given time interval.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association.

An excellent series of reference books are available (8/6 or 9/- post free) on electricity and productivity — "Higher Productivity" is an example. E.D.A. also have available on free loan a series of films on the industrial uses of electricity. Ask for a catalogue.

Issued by the Electrical Development Association
2 Savoy Hill, London, W.C.2

5954

CUT HERE

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Rare Earth Metals

SUCCESSFUL production of all the rare earth metals has now been achieved by Johnson Matthey & Co., Ltd. The rare earth elements or "lanthanons" comprise the fifteen elements from lanthanum (atomic number 57) to lutetium (71). Scandium (21) and yttrium (39), the first two members of the same sub-group in the periodic table, are similar chemically and in their atomic structure. Element 61, promethium, does not occur naturally, but one of its isotopes has been isolated form the products of nuclear fission. Together these closely related elements, with their compounds, form a hitherto little known but potentially valuable range of materials.

For some years active research on the rare earths has been carried out by Johnson Matthey, and supplies of the rare earths in their normal form as oxides have been available in several grades of purity. Improved techniques for the production of the metallic elements have now been brought to fruition, and all of the fourteen naturally occurring elements, together with the closely related elements scandium and yttrium, are now available in a variety of forms.

The metals are reduced from their fluorides with lithium, calcium or lanthanum in tantalum crucibles in an atmosphere of argon, and are then remelted in vacuum. Impurities are held at a very low level, and in some cases the purity is higher than has hitherto been achieved. Lanthanum, cerium, praseodymium and neodymium oxidise readily at room temperature and must be preserved in air-tight containers, but all the other metals, except europium, acquire no more than a superficial tarnish on prolonged exposure to the air at room temperature. Europium is highly reactive, and therefore difficult to preserve and handle as metal.

All of the sixteen metals have been remelted into ingots or rods, and lanthanum, cerium, neodymium, praseodymium, yttrium and gadolinium have been successfully extruded and subsequently drawn to fine wire.

Johnson, Matthey and Co., Ltd., 73-83 *Hatton Garden, London, E.C.2.*

Oil Burner Control

COMPLETELY foolproof safety control for all types of oil burners is claimed to be provided by new fully automatic oil burner sequence controller combined with flame failure control and self-checking circuit. Using a photo-resistive photocell capable of operating the contactor direct, and a synchronous motor timing device, this unit ensures accurate repetitive timing cycles, and has eliminated the need for valve amplifiers or magnetic amplifiers and bi-metal controls.

The control circuitry has been designed to fail to safety under every condition, for example :—

(a) A safe start relay is incorporated to ensure that the photocell is in darkness when the thermostat calls for heat. If the photocell has been left out in the open at this point the unit will not start up and an external warning bell will be energised.

(b) Should the cell leads short, the unit will not start up and the warning bell will be energised.

(c) Should the time clock cut off the supply whilst the motor is moving through the oil period, then on re-establishment of the supply the motor will continue its cycle without bringing on the oil and will start a new cycle at the correct time.

(d) Two purge periods have been incorporated—the first at the commencement of the day's operations, and the second from the lockout position to the re-commencement of a new cycle.

All time periods can be varied to suit any type of burner and to comply with L.C.C. and B.S.I. specifications. In the case of heavy oil burners, where a purge of the oil line is required, an additional cam and switch can be incorporated to energise the solenoid valve for a pre-determined period for this operation to be performed automatically with this same unit.

Photoelectronics (M.O.M.), Ltd., Oldfields Trading Estate, Oldfields Road, Sutton, Surrey.

Heated Lid for Aluminium Holding Pots

To help light metal foundries casting aluminium and aluminium alloys, the Electric Resistance Furnace Co., Ltd., have introduced a heated crucible cover fitted with solid rod heating elements operating at low voltage. This lid is designed to maintain the temperature of liquid aluminium in the production of high quality metal, either by holding at temperature for several hours, or by inducing into it during the holding period, nitrogen or dried chlorine gas. Compared with the wire wound or tape elements normally used for this purpose, the elements fitted to the Efco crucible cover enable much higher loadings to be used and a greater intensity of heating to be obtained over a small surface area. The elements have a very long life and are easy to install and remove : they are connected to the tranformer by flexible cables. The lid is fitted with a lifting hook and a crane is used to place it on a crucible, where it is positioned by four bosses round its perimeter. The lid stands on these bosses on an insulated base during idling periods. The heated lid can be made to fit existing holding pots of normal capacities or, alternatively, complete crucible assemblies can be supplied.

Electric Resistance Furnace Co., Ltd. Netherby, Queens Road, Weybridge, Surrey.

Centralised Level Control

FIELDEN ELECTRONICS, LTD., announce that a development of their well-known Tektor Minor level controller enables up to 150 ft. of coaxial cable to be used between probe and unit, and multiple construction of electronic units enables centralised or grouped indication of level. A single Tektor consists of a probe connected to an electronic unit, the probe being installed on the container. The increase in interconnecting cable length means that

Hand cleanser dispenser.

the unit may be conveniently situated at ground level for ease of access or maintenance. If centralised level control is required, this extension of cable length enables all electronic units to be brought together from different parts of the plant and housed in one case. The interconnecting coaxial cable is supplied with the instrument and no other cables are required from probe to unit. Installation costs are therefore cut to a minimum with multiple construction because only one mains supply cable need be run to the multiple unit. With the Fielden capacitance system of level control (originated and patented by this company over ten years ago) there are no electronics on the container.

Fielden Electronics, Ltd., Wythenshawe, Manchester.

Hand Cleanser Dispenser

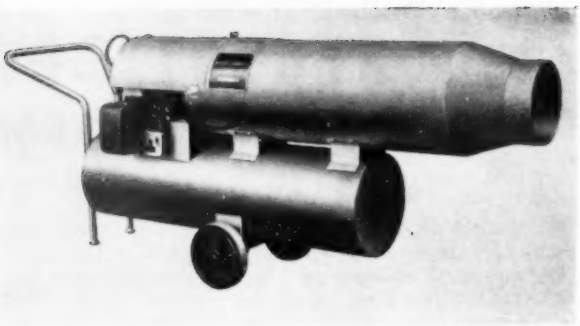
THE new Spenso dispenser for hand cleanser, recently introduced by Deb Chemical Proprietaries, Ltd., is stated to cost less than half the price of a normal dispenser. It consists of a bracket plugged to the wall on which rests a 1 gal. can. The pump unit clips on the bracket and down over the lip of the can, and is tightened in position. There is also a dipstick by means of which the contents of the can are easily checked. The new dispenser is claimed to eliminate waste, drips and pilfering.

Deb Chemical Proprietaries, Ltd., Forfar Chemcial Works, Belper, Derbyshire.

Portable Hot-Air Unit

THE Neo-Jet oil fired, hot-air unit has been designed to provide a really portable unit, supplementing the well-known range of Newstad portable mould dryers. It is a streamlined and completely mobile unit, light but robust in construction, and has capacity to deliver 800 cu. ft./min. of air at temperatures up to 300° C. Experience has shown that for drying complicated floor moulds it is essential that large quantities of hot air are available so that all parts of the mould are evenly dried, and the Neo-Jet aims to meet this requirement.

The unit is fully automatic and operates from a 15 A switch. When switched on, the spark ignition operates, the fan starts and the pump comes into operation—hot air being emitted within two or three seconds. The unit



Neo-Jet portable hot-air unit.

burns 35 seconds viscosity oil at a rate of 0·3–1 gal./hr. The cylindrical steel tank holds 15 gal., and with a full tank the unit weighs only 250 lb.

Modern Furnaces and Stoves, Ltd., Booth Street, Handsworth, Birmingham, 21.

Pyroclean No. 201

PYROCLEAN No. 201, recently introduced by the Pyrene Co., Ltd., is an inhibited acid-base material specifically formulated for the removal of heavy phosphate scale and sludge from heating coils in Parkerizing and Bonderizing tanks and similar installations. It is also suitable for descaling the barrels used in rotary barrel Parkerizing plants, and for cleaning stand-pipes and jets from Spra-Bonderizing installations.

Removal of the scale is effected by simple immersion in the cold solution for periods varying from about an hour—with very thick layers of scale, overnight immersion may prove necessary.

The Pyrene Co., Ltd., Metal Finishing Division, Great West Road, Brentford, Middlesex.

Additions to Recorder

INCREASED facilities, making for even greater versatility in their high speed potentiometric recorder, are announced by Sunvic Controls, Ltd. Single trace and 2, 4, 8 or 16 point multi-trace instruments are now available with standard facilities consisting of any one of 13 different input units and a choice of three different chart drive gear boxes. Additional facilities include alarm and control contacts, solenoid pens, retransmitting slidewire, a digitiser so that the recorder output can be shown on an "in-line" display or used to operate a printer, and fast/slow speed recording timer. An integrating system for use with single trace instruments is being developed.

The input units include four millivolt pattern with "plug-in" range change assembly, alternative scale spans, and either with or without zero shifts. There is a choice of 8 temperature input units with alternative scale spans, automatic cold junction compensation or external reference, and four-position range switch or miniature range-change relays with or without zero suppression. Alternatively a high impedance input unit can be supplied. Chart drive gear boxes are of the lever-change type to which change wheels can easily be fitted, giving, in all, 27 different chart speeds varying from 1 in./hr. to 3 in./min.

Recorders are normally supplied with a constant

current supply unit which has an accuracy of ±0·1% over a 1,000 hour period. Instruments can be supplied with a speed of response of 1 sec., a guaranteed calibration accuracy of ±0·5% f.s.d., and (for high impedance instruments) a sensitivity of ±0·25% at 10 MΩ with a scale span of 15 mV.

Sunvic Controls, Ltd., P.O. Box No. 1, Harlow, Essex.

Contact Welding Electrode

PHILIPS ELECTRICAL, LTD. are now marketing a new zircon iron powder-coated electrode—the C.16—which has been specially developed for rapid, trouble-free contact welding of all mild and low alloy steels in downhand, standing fillet, and horizontal-vertical positions. The mechanical properties—good ductility and high impact value—and soundness of the deposits are claimed to be better than those for conventional low hydrogen electrodes, making it particularly suitable for the demanding conditions of nuclear engineering. The welds produced are flat or slightly convex and have a neat and clean appearance: slag is self-removing. The C.16 has been approved by the Ministry of Transport and Lloyd's Register of Shipping.

Philips Electrical, Ltd., Industrial Products Division, Century House, Shaftesbury Avenue, London, W.C.2.

Heating Element for Enamelling Furnaces

THE development of the Incandescent Jetube radiant heating element for use in vitreous enamel fusing furnaces was referred to in a paper to the Scottish Section of the Institute of Vitreous Enamellers in February 1958. This brief mention aroused considerable interest, and since that time two prototype furnaces using specially designed Jetubes have been built and tested by the Development Division of the Incandescent Heat Co., Ltd. Now the first batch furnace using this system has been built for an important vitreous enamelling works, and will be in service in a few weeks. A continuous split crown furnace, also heated by Jetubes, has just been commissioned at the works of Smart and Brown, Ltd. Spennymoor, Co. Durham. The Jetube radiant element (which may be gas or oil-fired) gives an amazing flexibility of operation, and allows the use of a highly insulated furnace structure with low thermal storage. Consequently, fuel consumption is low and output is greatly increased. Jetubes have already gained wide acceptance in industry as heating elements in batch and continuous furnaces for carburizing, hardening, annealing and stress-relieving.

The Incandescent Heat Co., Ltd., Cornwall Road, Smethwick, Birmingham.

High Vacuum Furnace

VACUUM RESEARCH (CAMBRIDGE), LTD., have recently made for, and to the design of, the Metals Division of Imperial Chemical Industries, Ltd., equipment for the measurement of Young's Modulus for a number of metals at temperatures up to at least 1,000°C. and in high vacuum.

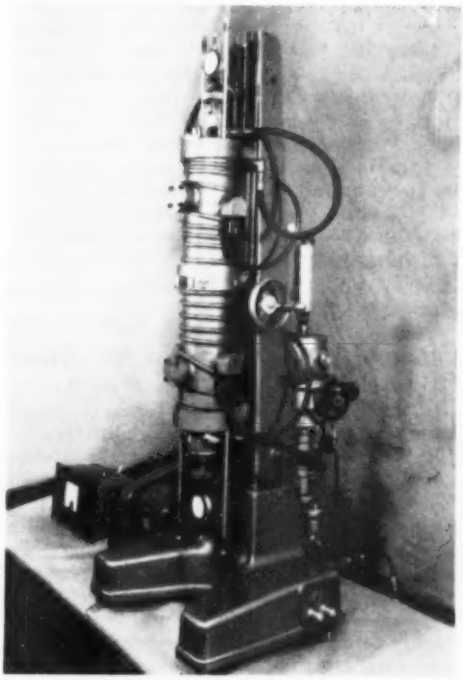
The interior of the water-cooled vacuum chamber contains two molybdenum-wound furnaces which heat the specimen in a working vacuum of 10^{-5} mm. Hg: the high vacuum prevents oxidation of the metal specimen at elevated temperatures. The high precision mechanisms seen on the top and bottom of the furnace chamber are used to control the special electrodes, inside the furnace, which are required in the acoustic method of Young's Modulus measurement using an electrostatic drive. Special techniques are incorporated in the design and construction of this apparatus to ensure a vacuum tightness of the various joints which are broken to allow insertion of the specimen and electrodes. The leak rate of the furnace at 1200°C. is less than one clusec.

We are advised by Vacuum Research that in addition to being manufacturers of special high vacuum apparatus, they also have facilities for the design of prototype equipment.

Vacuum Research, (Cambridge), Ltd., Quayside, Bridge Street, Cambridge.

Transistorised Temperature Controller

THE first of the new Fielden Bikini range of transistorised instruments is a precision temperature controller claimed to have a differential of only 0·5°C. high calibration accuracy and very high long term stability. The instrument is housed in a small meter type case and occupies a panel space of only 4½ in. diameter. The scale, which is 9 in. long, is calibrated directly in °C. or °F., and the bold pointer is set to the required control temperature by a small knob in the centre of the instrument. A red lamp visible from the sides as well as from the front indicates the control action. The meter type case is completely sealed and contains no galvanometers, pivots or other delicate moving parts, and the instrument can be mounted at any angle, for example, on a sloping control desk. Control can be obtained at any temperature between −200°C. and +500°C., with a minimum temper-



High vacuum furnace.

Bikini temperature controller.

ature range span of 50°C., and there are twelve standard calibrations in °C. and °F.

A platinum resistance element is used at the temperature measuring point, this being housed in a robust stainless steel sheath of ¼ in. diameter. Ordinary connecting cable is used between the measuring point and the instrument and this can be up to 300 ft. in length without introducing errors. The control action is on/off, either electrical or pneumatic. The electrical contacts give changeover switching at 5 A., 250 V. whilst the pneumatic valve requires 17-20 lb./sq. in. input. An interesting feature is that the electrical or pneumatic control relay can be located up to 300 ft. away from the instrument itself, and only simple light duty cable is required between the instrument and the relay.

The electronic circuit is of an advanced design, and is the result of three years' intensive work at the Fielden Research Laboratories, Bangor. The instrument is completely transistorised and will operate from a 12 V. D.C. supply, components operating well below their maximum rating. Practically no heat is generated and, of course, there is no "warming up" time. The low voltage and current allow handling of the instruments without fear of electrical shock, and they can be used safely in hazardous areas; an Intrinsic Safety Certificate is pending. Further, only light duty cable is required between the instrument and its power supply. Inexpensive power supply units are available to provide the necessary 12 V. D.C. from the usual supply mains. These can be supplied for one or a number of instruments, and can be fitted with or without the electrical control relays.

Fielden Electronics, Ltd., Paston Road, Wythenshawe, Manchester, 22.

Chemical Brightening of Aluminium

THE S process, a new development in the chemical brightening of aluminum, is particularly suitable for aluminium pressings and body trim. Brilliant specular reflection is obtained on 99·7% aluminium in addition to super purity aluminium and aluminium-magnesium alloy. On alloys such as N4 magnesium alloy and N9 magnesium-silicon alloy, a decorative semi-bright finish is produced.

A number of advantages are claimed for the new process. The acid concentration of the solution is low and the operating temperature is only 120-140°F. Furthermore, no spray is evolved and the process is free from highly corrosive or obnoxious fumes, exhaust being necessary with larger tanks only in order to remove fumes while acid additions are being made. The S solution is used in a tank lined with Canning Vulcron rubber or other approved material. The process time is 1-4 min., depending upon the initial surface condition of the metal. The fact that the chemical reaction virtually ceases when the articles are removed from the tank greatly simplifies the handling of components, and avoids the necessity for extremely rapid transference between the process tank and the swill.

The S solution contains 60ml. of nitric acid and 22 ml. of hydrofluoric acid, together with 80 ml. of S1 additive and 10 ml. of S2 additive. The low concentration of the S solution combined with its long operating life enables chemical brightening to be carried out at a very low cost.

W. Canning & Co., Ltd., Great Hampton Street, Birmingham 18.

Headband Magnifier

ELLIS OPTICAL COMPANY have designed and produced a headband magnifier that facilitates examination of minute detail by providing magnification with good stereoscopic effect. The lenses are accurately ground with the requisite prismatic effect to prevent eyestrain, even when worn continuously. The focal distance is approximately 8 in., the field of view large, and the magnification 2¼ times.

Constructed of a strong, lightweight plastic material it can be worn for long periods without discomfort. The hood, by extending over the top and side, shields the eyes from glare, whilst the object viewed may be under the most brilliant illumination. The lower side is open, allowing unrestricted downward vision, an advantage at once apparent to those using small tools, or wishing to make notes, both hands being free for this purpose. Spectacle wearers can use this magnifier without removing their glasses.

Ellis Optical Company, Mayday Road, Thornton Heath, Surrey.

Specimen Pre-Grinder

A RECENT addition to the range of metallurgical equipment manufactured by Nash & Thompson, Ltd., the Nashton Pre-Grinder has been designed to provide a simple method for wet or dry grinding of specimens for microscopic examination. The grinder consists of a ground glass plate and a Perspex frame for holding four grades of waterproof abrasive papers, which are washed continuously by water sprays incorporated in the head of the Perspex holding frame, The assembly is mounted in a polythene tray with a drain exit.

Specimens up to 1⅜ in. diameter can be ground in the normal manner, and it is recommended that they be turned through 90° after each paper. A slower grinding speed with an increased pressure is recommended to take full advantage of the wet grinding technique. Worn papers are replaced in a few seconds. Due to the continuous water feed, there is no necessity to rinse the specimen when changing from one grade of paper to the next, and the abrasive effect of the paper is maintained since the loose products are washed away. It is claimed that the use of this equipment is more efficient and economical than the usual grinding techniques and that, as the grinding papers are held permanently in position, wastage and contamination due to the mixing of grit sizes is also avoided. Specimen preparation time is reduced and abrasive paper life is increased when using the pre-grinder.

Nash & Thompson, Ltd., Hook Rise, Tolworth, Surrey.

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if you were buying a Carburising Furnace?

CARBURISING Furnaces cost quite a lot of money and the most careful consideration is necessary before choosing any specific make.

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Literature will be sent on request or our Metallurgist will visit you at your convenience.

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The new DELTA heating element, used by leading furnace builders throughout the country, facilitates exceptionally accurate temperature control, to a maximum of 1550° C. It also offers outstanding economic advantages. It will give you

* *Easier Installation*
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* *Increased Efficiency*
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* *Greater Safety*

These are the results of more than a quarter-century's unmatched experience. We shall be glad to hear from furnace builders and furnace users who would like full technical details of GLOBAR DELTA elements.

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CURRENT LITERATURE

Book Notice

PROCESS INTEGRATION AND INSTUMENTATION

200 pp., 141 illustrations. London, 1959, Electrical Development Association, 2 Savoy Hill, London, W.C.2. 8s. 6d. (by post 9s.)

THIS new book is the latest addition to the Electrical Development Association's series on "Electricity and Productivity." There have appeared recently a number of books on instrumentation, control, and automation, but few of these have dealt with the necessary units of equipment—"the building blocks"—which together allow various degrees of automatic working to be achieved. "Process Integration and Instrumentation" is designed to fill the gap, and has been written with the requirements of the industrial manager and production executive of the medium and small concern very much in mind. It will, however, be valuable for all industrialists and should make a contribution to the improvement of electrical load factor.

In the far-reaching changes in manufacture and in deployment of men and machines which are taking place in industry, measurement is recognised as a fundamental factor, in fact the science of measurement which embraces metering and recording has reached a high state of perfection. Control engineers are rapidly developing the further means which will lead to fully automatic production. When these are realised, as they already are in some processes, machines will have approached much nearer to the ideal of producing the highest quality at the lowest cost.

A study of this new book indicates that the steps which lead from detection and measurement to indication, recording and, eventually, to automatic control are intricate and impinge on a wide range of specialised skills. Chemistry, physics, electrical, mechanical, electronic and nuclear engineering are involved, it is shown, all of which have their peculiar and rapidly extending vocabularies. The book outlines in simple form the means by which the variables occurring in manufacturing can be sensed, measured and controlled with the ultimate object of achieving a more completely and perfectly integrated process.

The new book covers an extremely wide field and is written in a very readable style without recourse to mathematical formulae or references to abstruse points of design. The titles of the thirteen chapters into which it is divided are: Modern Manufacturing, Automatic Control, Sensing, Instruments and Instrumentation, Electrical and Electronic Links, Actuators and Servomotors, Industrial Applications, Computers, Control of Machine Tools, Movement of Materials, Quality Control, Design and Servicing, and Progress Towards Automation.

Trade Publications

L. LIGHT & CO., LTD., of Colnbrook, Bucks, recently issued their 1960 Catalogue of over 5,000 substances which embrace organic chemicals for syntheses, biochemicals, enzymes and analytical reagents. Since their 1958 list, the range has been increased by 1,000 items, thus keeping pace with the latest developments in many scientific fields. During the last two years great interest has developed in semi-conductor materials. To satisfy these requirements, the company can now offer a wide range of ultra pure (99·999%) elements such as gallium, antimony, arsenic and phosphorus. They also supply very pure inorganic salts such as cesium iodide and metal fluorides for growing single crystals for the optical industry.

THE Mond Nickel Company have produced a further publication in the series dealing with the development of S.G. Iron. The new publication, which is fully illustrated, describes in detail the properties of S.G. Iron and lists a number of important applications. The section on properties includes many tables and information on strength, toughness and ductility, elasticity, fatigue resistance, hardness, wear-resistance, thermal properties and corrosion-resistance. Among the applications featured are examples of the use of this material in power, transport, mining and chemical plant, civil engineering and agriculture.

THERE are many factors which govern the choice of a roofing material. In order that the full benefit may be obtained from the many advantages which copper has to offer in this respect, the Copper Development Association have issued a new publication entitled "Copper Roofing." In addition to its use for weathering, other applications of copper sheet and strip in building, such as rainwater goods, lightning conductors and damp-proof courses, are also described. The essentially practical nature of this book is exemplified by the inclusion of a section devoted to the various tools required for this type of work. "Copper Roofing" replaces two previous C.D.A. publications—No. 42 "Copper Flashings and Weatherings" and No. 53 "Economy Copper Roofing" and is available free upon application to the Association at 55 South Audley Street, London, W.1.

BAKELITE, LTD., announce the publication of a new booklet entitled "Bakelite Epoxide Resins and Their Applications," which outlines some of the uses of the comprehensive range of epoxide systems marketed by the company. The booklet is intended for use in conjunction with the large number of advance information sheets and technical memoranda already issued on specific applications of Bakelite epoxide systems. In this connection, the chart entitled "Guide to Publications on Bakelite Epoxide Resins," which is enclosed in the booklet, will be found useful for reference purposes. Copies of the publication are available from Bakelite, Ltd., 12–18 Grosvenor Gardens, London, S.W.1.

A NEW publication from the general chemicals department of Albright & Wilson (Mfg.), Ltd., lists close on four hundred regular products handled every day by this department. These general and fine chemicals are detailed in alphabetical order; a brief description of physical form and the nature of the packs in which the products are available is useful additional information. Albright & Wilson (Mfg.), Ltd., is the largest U.K. manufacturing company within the international Albright & Wilson chemical group. The main producer of phosphorus and its derivatives in Europe—its interests

embrace the production and sale of phosphorus, phosphoric acid, organic phosphorus compounds and the development of a wide and growing range of industrial finishing processes.

A NEW Metalectric furnace leaflet, No. M4B, gives details of the standard box type furnaces made by the company. These are designed for operating at temperatures up to 1,000° C., and are suitable for general purpose heat treatment in the workshop and toolroom, particularly for hardening, normalising and annealing. The main features of the units are described and a list given of the standard sizes, ranging from 10 kW. to 42 kW. rating. Reference is also made to the possibility of fitting the standard P.T. furnaces with strip heating elements, so that they may be operated at temperatures up to 1,200° C., and to the possibility of modifying them for use with controlled atmospheres.

WE have received from The Morgan Crucible Co., Ltd., a copy of their latest publication (AE.66) entitled "Salamander Plumbago Stoppers and Nozzles." This is a single sheet leaflet illustrating Morgan products for bottom teeming ladles, the features claimed for them being smooth finish and accurate shape, high temperature strength, resistance to erosion and thermal shock, and non-wetting surfaces which prevent sticking stoppers.

RECENT Kent publications include No. 265—instruments for temperature measurement; AS1 and 2—after-sales service; and 1518—spare parts list for the Commander integrator (tractor wheel type). The temperature measurement leaflet sets out the principle of operation on which the Multelec instruments are based and their general features, before considering in more detail manual and self-balancing instruments for indicating, recording and controlling temperature. Finally, the specification and dimensional details are given. Leaflet AS1 outlines the after-sales service provided by George Kent, Ltd., which includes a periodical inspection contract scheme, and AS2 details the service areas in the British Isles and the addresses of the appropriate district engineer or agent.

THE issue of *Wiggin Nickel Alloys*, No. 54, features a new and successful application of Nimonic 90, one of the Wiggin series of Nimonic high temperature alloys, as a material for extrusion dies. There is some departure from normal practice in this issue of the publication, in that, reference is made, under the heading of "Some Back-Room Alloys," to materials which are as yet, not commercially available, but where research and development indicate the possibility of their ultimate successful production. Also included are illustrated articles on sea-water evaporators; welding operations on AT nickel; and, among other subjects, an interesting account of the method of recording movement of bird and fish life by metal ringing. There is a wealth of information on metallurgical materials and modern industrial applications in this publication and copies can be obtained free on request from Henry Wiggin and Co., Ltd., Publicity Department.

AN eight-page booklet "Aluminium for Thermal Insulation," recently issued by Northern Aluminium Co., Ltd., explains why aluminium is both a good reflector of heat and a poor radiator, keeping interiors cool in summer and warm in winter. Since this derives from a surface effect of the aluminium, the thickness of the sheet need only be sufficient for its structural requirements, with much saving in the weight; moreover, aluminium's outstanding durability, even in normally aggressive atmospheres, ensures a long trouble-free life for the system incorporating it. The booklet also illustrates several recommended systems in which aluminium sheet in various profiles is used with and without additional insulation, and there are notes on aluminium foil and its use as a vapour barrier.

PRIDE of place in the November 1959 issue of *Lead News*, a periodical publication of the Lead Development Association, is given to an article describing a new plant for the electrolytic refining of lead using a sulphamic acid electrolyte. This plant is claimed to have considerable technical and commercial advantages over a thermal refining plant which it replaces, lead of 99·995% purity being obtained. On the uses of lead, an article on the flat oil-filled super-tension electric cable discusses the role which the lead sheath plays in its successful operation. Other features include a description of a gamma-ray pinhole camera for the accurate location of a source of intense radiations within a general region; lead as a super conductor; lead glass for radiation protection; the combination of lead and plastics in unlubricated bearings; the salient features of good lead burning; and a reference to a process for the refining of titanium in which the metal is dissolved in lead and subsequently precipitated therefrom.

WE have received from the Foundry Division of Electric Resistance Furnace Co., Ltd., an illustrated leaflet describing the Efco-Brown Boveri portable electric mould driers. These are designed for drying floor moulds or large box moulds and operate by forcing hot air not merely over the mould surface but through the sand itself, giving a quicker and more efficient drying than is normally achieved with hot gas from fuel-fired stoves.

AN unusual application of ultrasonic flaw detection equipment—measurement of fat in breeding pigs—is discussed in the first issue of *Pulse*, which is designed to provide regularly information on Kelvin Hughes non-destructive testing equipment and electronic instrumentation. Readers of *Metallurgia* will no doubt find greater interest in the discussion of the problems associated with the testing of butt welds in complicated sections; an account of the recording of voltage and current variations during research into the arc welding of rare metals; a description of the application of a portable ultrasonic flaw detector in a steel stockyard; and the first of a series of four articles on the subject of high speed pen recording equipment.

Books Received

"Property Measurements at High Temperatures." By W. D. Kingery. 416 pp. inc. subject and author indexes. New York and London, 1959. John Wiley and Sons, Inc., and Chapman and Hall, Ltd. 132s. net.

"Kinetics of High-Temperature Processes." By W. D. Kingery. 326 pp. inc. subject and author indexes. Massachusetts, New York and London, 1959. Technology Press of Massachusetts Institute of Technology and John Wiley and Sons, Inc.; Chapman and Hall, Ltd. 108s. net.

"Studies in Crystal Physics." By M. A. Jawson. 42 pp. London, 1959. Butterworth's Scientific Publications. 10s. 6d. By post 7d. extra.

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LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
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The Routine Evaluation of Raw Titanium

By P. S. Crowther,* M.Sc., M.I.Mech.E. and H. Bradley,† M. Met.

Commercial raw titanium is now so pure that the analytical determination of the minute allowance of oxygen and nitrogen in the metal is a matter of very great difficulty, and in practice the hardness of the metal is taken as an indication of its degree of freedom from these impurities. An account is given of a procedure developed for the routine evaluation of raw titanium by hardness tests on arc-melted buttons. A new consumable-electrode furnace for preparing the buttons is described, together with the precautions taken in sampling, melting and hardness testing to ensure a high standard of accuracy and reproducibility.

ALTHOUGH the impurity content of commercial raw titanium has been reduced to a low figure by the measures taken to refine the raw materials and to avoid contamination during production, it has not yet proved possible to reduce the oxygen and nitrogen contents to an insignificant level. The influence of even very small proportions of these interstitial impurities on titanium is much greater than on other commercial metals, and they largely govern the quality of the material.

Unfortunately, there is no simple analytical method for the determination of the impurities in titanium, and manufacturers and purchasers of raw titanium must therefore resort to a non-analytical method for assessing the quality of the product. As is well known, the method which has been generally adopted makes use of the rapid increase in the hardness of titanium with increasing content of impurities, especially oxygen and nitrogen, and consists essentially of measuring the hardness of small ingots or buttons made by melting the samples to be evaluated under carefully controlled conditions, whereby further contamination is prevented.

The melting of the sample is, however, not the only stage of the evaluation procedure in which serious errors can arise; each of the operations involved offers equally important problems, and only by careful attention to detail at all stages is it possible to achieve the accuracy required of what is, in effect, an analytical method. This article discusses these problems and describes the technique now adopted by I.C.I. for the evaluation of raw titanium.

The raw titanium produced by I.C.I is made by the sodium reduction method and is in the form of small granules from $\frac{3}{16}$ in. down to dust. Most of the material lies in the range 5–100 B.S.S., with not more than 1% retained on a 5 B.S. sieve and not more than 20% passing a 100 B.S. sieve.

The technique described in this article has been developed for the evaluation of this material or other products of fairly small particle size. The coarser product of the Kroll (magnesium reduction) process, which consists largely of pieces of sponge up to $\frac{1}{2}$ in. in size, offers difficulties in sampling—in fact, the problem of obtaining the small representative samples ordinarily used for evaluation has not yet been satisfactorily solved.

Moreover, material of this size is too coarse to make sound $\frac{1}{2}$ in. square compacts for the consumable electrodes used in the method of melting the samples herein described, and the tungsten-arc furnace, with its attendant disadvantages, must be retained.

Sampling

The first essential in the evaluation of any bulk product is to ensure that the sample is truly representative. Owing to the wide range of particle sizes in the product, segregation is likely to occur and mechanical samplers are used to obtain truly representative samples. Experience has shown that neither rifflers nor coning-and-quartering methods are suitable. A sample removed from a drum by a "spear" is liable to be most unrepresentative, and this device is never used.

The sampling of a bulk lot falls into two stages: preparation of a laboratory sample, usually several pounds in weight; and the reduction of this to the portions required for analysis, including hardness evaluation. The first stage is best achieved by passing the whole contents of a drum, or an entire batch, through a mechanical sampling machine, which may be either the oscillating hopper type giving 2 to 1 reduction in each pass, or a rotary machine giving a reduction of up to 12 to 1. In the latter case, the speed of rotation is such that each sample consists of 60 or more increments.

The laboratory sample is further reduced in a rotary sampling machine. Separation into sub-samples equal in number to the samples required for evaluation is made at the earliest possible stage; reduction of the sub-samples to the size required is then achieved by rejecting opposite quarters delivered by the machine and combining the remainder after each pass, the quarters to be rejected being alternated. Some modification of this procedure may be necessary in the later stages to ensure

* Research Department, Metals Division, Imperial Chemical Industries Ltd.
† Research Department, General Chemicals Division, Imperial Chemical Industries, Ltd.

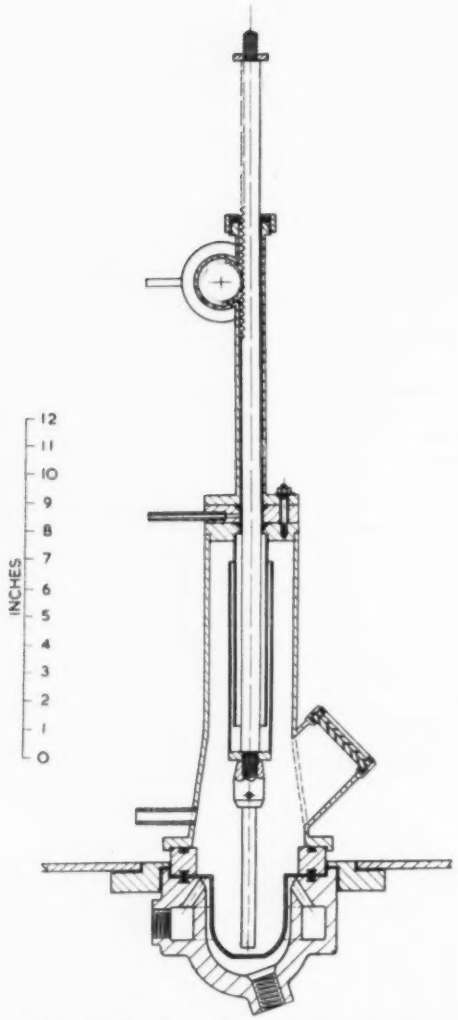

Fig. 1.—Details of furnace construction.

that the final samples are of the size required. Machines in which the spout is rotated and the receivers fixed, or in which the spout is fixed and delivers into four receivers on a rotating table, are equally suitable. In either case the speed of rotation is preferably such that each sample consists of 60 or more increments. The final weight of sample used for melting into buttons is 75 g. per button.

Some fire hazard is associated with the handling of finely-divided titanium, but nitrogen blanketing has not been found necessary for drum and laboratory samplers, though desirable on larger machines. The sampling machines are for preference installed in special rooms, usually with related equipment, and all electrical equipment should be flameproof.

Preparation of Buttons

Melting Furnace.—Since molten titanium reacts with all refractory crucible materials, it is common practice to melt evaluation samples under argon in arc furnaces based on that devised by von Bolton[1]. Several designs of furnace have been developed, one of the best known being that of the Battelle Memorial Institute[2, 3], while later furnaces have incorporated refinements such as multiple hearths for melting several samples consecutively at one charge, and arrangements for gettering the furnace atmosphere. All, however, are similar in principle: the sample, contained in a water-cooled copper crucible or hearth, is melted by an arc struck between the sample and an upper, water-cooled electrode with a tungsten tip.

Experience in this company has shown, however, that contamination of the melt with tungsten cannot be completely eliminated in this type of furnace, even when thoriated tungsten tips are used and the current density in the tip is kept as low as practicable. The hardness values obtained on buttons melted in this way are therefore liable to be too high, and a more reliable method has been developed, based on the use of a small consumable-electrode furnace. In this method most of the sample to be evaluated is compacted into a rod to form the upper, consumable, electrode, and the arc is struck between this and the remainder of the sample contained in the water-cooled copper crucible. Thus, no extraneous matter is introduced into the arc and contamination from the electrode is avoided. No provision is made for gettering the furnace atmosphere; with this small furnace, the omission of such a precaution would give rise to an error of less than $\frac{1}{2}$ D.P.N. (diamond pyramid number) in the hardness of the final button.

The melting furnace is shown in Figs. 1 and 2, while Fig. 3 is a photograph of a complete assembly of two furnaces with their common gas system and electrical equipment.

The hearth of the furnace, which forms the lower electrode, is a $\frac{1}{8}$ in. thick spun copper crucible with a brazed-on flange, the electrical connection being bolted to a lug integral with the flange. This is not shown in

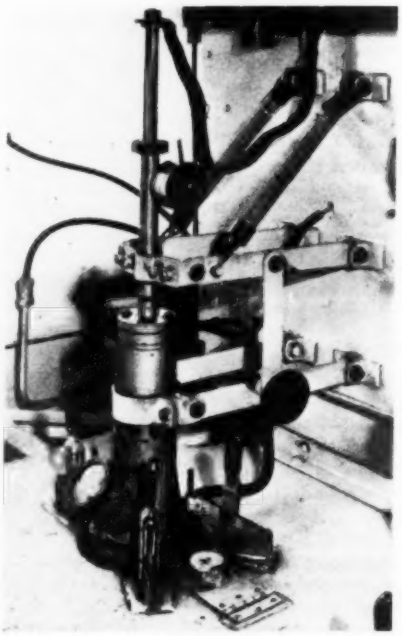

Fig. 2.—Furnace body.

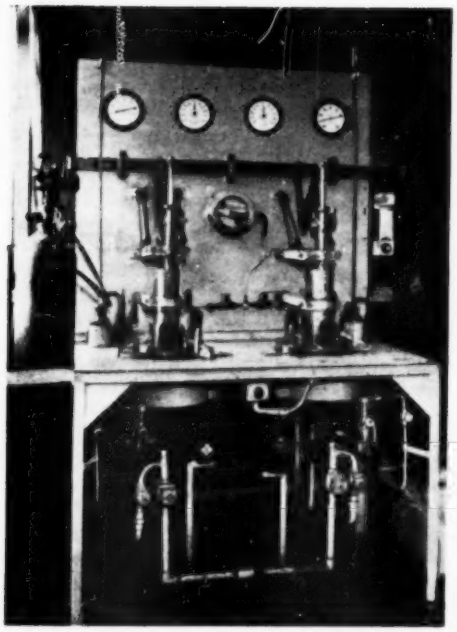

Fig. 3.—Two evaluation furnaces side by side.

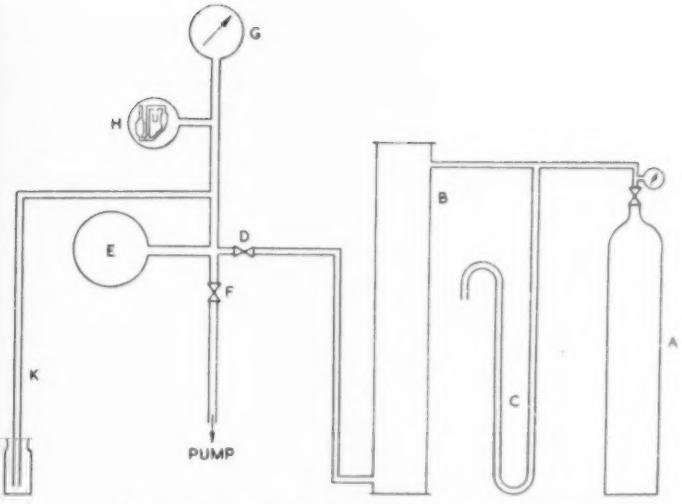

Fig. 4.—Diagrammatic sketch of the gas system.

Fig. 1, but lies below the top of the furnace table and is accessible through the hinged flap seen in the foreground of Fig. 2. The crucible is seated in a water-jacket let into the table top, and is insulated from the furnace cover by a Tufnol ring. The cover is held in place by toggle clamps bolted to the table top (Fig. 2); these clamps apply sufficient pressure to make gas-tight joints with the O-rings recessed into the insulating ring, and also a water-tight joint between the crucible flange and the O-ring in the joint face of the water-jacket.

The upper electrode is a copper rod carrying at its lower end a copper compact holder; the compact to be melted is inserted into a rectangular hole in the bottom of the holder and gripped by an Allen screw. The upper end of the electrode rod passes through the top of the cover into a guide tube and is raised and lowered by a rack and pinion. Two small O-rings in grooves in the top of the cover form a gas-tight seal with the rod and, as an additional precaution, a bleed of argon is admitted between the O-rings.

During melting, some splashing of molten titanium occurs, and if any droplets of solidified metal adhered to the electrode rod they would be carried up with it when raised again, causing damage to the O-rings and to the rack and pinion. To prevent this, the rod is protected by two thin brass tubes which telescope into each other when the rod is raised. The progress of melting is watched through a wide sight-tube provided with a dark window of filter glass protected on its underside by a disc of heat-resisting glass. The furnace cover is carried by the hinged brackets seen in Fig. 2, the weight of the assembly being counterbalanced by the two springs.

The furnace operates on direct current, the consumable electrode being connected to the positive pole of the supply. A push-button conveniently positioned on the furnace table enables the current to be broken immediately on completion of melting or in an emergency.

Before melting it is, of course, necessary to remove all air from the furnace and to fill it with pure dry argon. The system employed for this is shown diagrammatically in Fig. 4. Argon of 99·99% purity is supplied from the cylinder *A*, via a silica-gel drying column *B*. The pressure at the cylinder valve is adjusted to 10 lb./sq. in., the mercury lute *C* ensuring that a pressure exceeding 15 lb./sq. in. cannot be applied to the system. A Saunders valve *D* enables the gas to be shut off from the furnace *E* and a second valve *F* isolates the system from the vacuum pump. The pressure or vacuum in the system is indicated by a Bourdon pressure/vacuum gauge *G*, and a Vacustat *H* serves to measure low pressures when the system is evacuated. A barometric mercury seal *K* prevents the development of excess pressure in the furnace by permitting the escape of argon when this expands as the arc is struck.

The system is periodically tested to ensure that it is free from leaks. After pumping down to 0·1 mm., the pump is isolated from the system and the rate of increase of pressure noted. This must not exceed 1 lusec (litre-micron/second).

Evaluation Procedure.—The first step in evaluating a sample is the preparation of the 6 in. long × ½ in. square section compact which forms the consumable electrode and for this purpose a hardened steel die with a rectangular chamber 6 in. × ½ in. × 3 in. deep is used. From the 75 g. sample obtained as described earlier, 65 g. is weighed out and transferred to the die chamber. In filling the die, the sample is distributed as uniformly as possible along the length of the chamber by traversing the container several times along the mouth of the die while pouring in the granules. This even distribution is necessary since the whole of the compact is not melted when making the button, a stub 1–1½ in. long being left unmelted in the holder. That the error introduced by this is very small is shown by the reproducibility of the results obtained from a number of buttons made from one batch of titanium, properly sampled.

When all the 65 g. of granules has been transferred to the die it is levelled off and compacted under a load of 20–30 tons in a hydraulic press. The remaining 10 g. from the original 75 g. sample is retained and later

placed in the bottom of the crucible to form a pad on which to strike the arc. There are, of course, variations in the compression ratio of different samples, resulting in variations from the nominal ½ in. depth of the compact. This can to some extent be adjusted by altering the compacting load but, provided that the compact will enter the holder—and the hole in this is made slightly rectangular to cater for over-size compacts—it is unimportant, as the electrical contact is in any case made on one face only of the compact.

Before each run in the furnace, the copper crucible is thoroughly cleaned by pickling in 1 : 1 nitric acid, followed by washing in running water. It is then rinsed out with acetone and dried in a current of hot, clean air. One end of the compact is clamped in the holder on the lower end of the electrode, and the remaining 10 g. of granules from the same sample is placed in the crucible. With the electrode raised, the furnace cover is clamped in place. The furnace is then evacuated to 0·2 mm. of mercury or less for 5–10 minutes, isolated from the pump and filled with argon to atmospheric pressure. This evacuation and purging with argon is carried out three times, the furnace being finally left filled with argon at atmospheric pressure.

After turning on the water supply to the jacket, the open-circuit voltage is adjusted and the electrode lowered into momentary contact with the granules in the crucible, to strike the arc. As the compact melts it is fed into the crucible at a steady rate to maintain a short arc with a current of 400–500 A. When, after about 30 seconds, only about ¾ in. of the compact remains unmelted outside the holder, the arc is broken by means of the trip switch and the electrode is raised. The pressure within the furnace will fall below atmospheric as the argon atmosphere cools and contracts ; argon is therefore admitted to raise the pressure again to slightly above atmospheric, and the furnace is left to cool for about 10 minutes before it is opened and the button removed. After each run, the furnace is thoroughly wiped with a clean dry cloth, and the crucible again cleaned as described above.

Since the object of the evaluation procedure is to determine the impurity content of the sample, it is axiomatic that strict precautions must be taken throughout to avoid further contamination, especially by any substance containing oxygen or nitrogen ; air and water are the principal sources of trouble.

These measures must start with the sample itself, which is kept in a closed bottle until required for compacting. The compacting die is kept free from rust and oil, and the compact is not handled with moist or dirty hands ; on removal from the die it is placed in a stoppered container—boiling tubes are very suitable—together with the remaining 10 g. of granules from the same 75 g. sample.

It is obvious that the furnace must be free from leaks and the periodical leak test ensures this. It is only rarely that the permanent joints of the system, if properly made in the first place, give trouble. The usual sources are : damaged O-rings between cover and crucible, and possibly dirt or particles of titanium in the grooves ; burning of the Tufnol insulating ring ; mechanical damage to the flanges of the crucible, particularly under the O-rings ; and failure of the diaphragms of the Saunders valves.

One source of contamination during manipulation is imperfect drying of the crucible after cleaning ; warm air is used for this as the cooling of the crucible due to the evaporation of the acetone rinse may lead to condensation of moisture on it. Splashing of water into the crucible, or on to its flange, when replacing it in the water jacket must also be avoided. The jacket is emptied through a drain-cock before the furnace is opened, and the water is not admitted again until the furnace has been evacuated and purged in preparation for the next run. This last precaution not only serves to minimise the risk of splashing but also helps to prevent condensation of atmospheric moisture in the furnace between runs. When the furnace is left idle—e.g. overnight—it is closed and filled with argon to a pressure slightly above atmospheric to prevent ingress of air and moisture. It has also been found advisable to reject the first button melted each morning.

Discoloration of a button usually indicates that contamination has occurred during melting (though the absence of discoloration does not necessarily mean that there has not been contamination). It may, however, also be due merely to superficial oxidation occurring when the furnace is opened before the button has cooled sufficiently. Such superficial oxidation does not affect the hardness of the button and is easily avoided by increasing the cooling time. Unless the discoloration can definitely be attributed to this cause, however, the button is not used for hardness tests and the cause of the discoloration is investigated.

However great the care taken in the preparation and melting of the samples, the hardness figures obtained on replicate buttons are not exactly reproducible. The degree of reproducibility which can be expected in routine evaluation is discussed in a later paragraph. Too large a spread in the mean hardness values of replicate buttons is usually an indication that contamination is occurring during melting. If this is suspected, whether for the above or any other reason, the operation of the furnace is checked by melting and testing buttons from a large "standard" sample of material of known hardness, kept specially for the purpose. A similar check is also considered advisable whenever melting is resumed in a furnace which has been idle for more than two or three days.

Hardness Determination

Method.—Diamond pyramid hardness has always been used for button evaluation by I.C.I. Originally this was because it was the normal and preferred practice, but the relative merits of diamond pyramid and Brinell tests have been reviewed several times and the diamond pyramid test has always been retained. The main arguments in its favour are that a relatively small flat only is required, and that the manipulation involved is easier. The Brinell test using 1,500 kg., 10 mm. ball and 30 seconds is specified by A.S.T.M. in B.299–638. This test can only reasonably be performed on a relatively large flat prepared on the face of the button, whereas the diamond pyramid test can be carried out either on the face or on a flat formed on the edge, the latter being preferred on the grounds of convenience. The Brinell test, in which the individual impressions cover a greater area, might be expected to give more uniform results on the rather coarse-grained, cast structure of the buttons, but this is offset by the greater number of impressions

TABLE I.—EFFECT OF METHOD OF PREPARATION FOR TESTING ON DIAMOND PYRAMID HARDNESS OF TITANIUM BUTTONS.

D.P. Hardness Values of Titanium Button Surface (mean of 5 readings, 20 kg. load, 15 seconds)	Button A	Button B
1. Sawn with high-speed steel hacksaw, 18 teeth/in. and saw marks just removed with 14 in. bastard file	152	146
2. Saw marks completely removed with 14 in. bastard file	151	148
3. 14 in. bastard file scratches just removed with 14 in. smooth file	148	147
3A. Thoroughly polished with 320 grit aluminium oxide paper	148	not polished
4. Filed with 10 in. smooth file and for button A only scratches just removed with 320 grit aluminium oxide	140	141
5. Thoroughly polished with 320 grit aluminium oxide. (Two grades of paper would produce the same result more quickly)	142	139

which can be made with the diamond pyramid, and it has been found that five diamond pyramid impressions give the same variability as two Brinell impressions made on the same surface.

Technique.—Any method of removing metal to form a flat for testing is likely to harden the surface of the remainder, and with a new material it is necessary to determine the seriousness of this effect. This and the effect of load and duration of indenting have been investigated. The procedure finally preferred, within which minor variation is allowable, is to saw the flat and then use two grades of file and two or three of abrasive paper, each to remove the effects of the coarser grade used before. Typically, 12 in. or 14 in. bastard and 10 in. or 12 in. smooth files would be used, followed by 120 or 150 and 320 grit aluminium oxide paper and grade 2/0 emery polishing paper. Grinding was investigated as an alternative, but was no better in its results than filing and polishing, and was less convenient to do as titanium is difficult to grind. The effects of the various stages of treatment on the hardness values obtained are shown in Table I.

It was reasoned that if a superficial few thousandths of an inch was removed by pickling, the surface produced would be free from work hardening. A subsidiary experiment, consisting of pickling for increasing times until a constant hardness value was obtained, showed that 2 minutes in an aqueous solution of 16% HNO_3 and 8% HF was satisfactory, 0·002–0·003 in. being removed after the final polish. A series of tests was then undertaken to assess the results of the mechanical preparation. The procedure—i.e. grades of file and abrasives and times or number of strokes—was laid down in minute detail and, because the operation is one where a personal factor might reasonably be expected, a number of operators, some experienced and some unfamiliar with the work were used. The final average result of pickling was a decrease in hardness values of 2–3 points. In a more extensive but slightly differently organised series of tests the value was 1½ points. These values are just about relevant within the practical limits of the test, but are not held to justify the rather objectional operation of an HF pickle as a routine measure.

A load of 20 kg. for 15 seconds was used in obtaining all the results discussed so far. Since, however, a deeper impression involves a smaller proportion of the work-hardened surface material, it is to be expected that sensitivity to the method of surface preparation would decrease as the load increases up to a certain point, which will depend on the depth of the hardened layer. The effect of load has been investigated, and particularly of an increase from 20 kg. to 30 kg. and it appeared that

TABLE II.
TYPICAL RESULTS OBTAINED DURING ROUTINE TESTING.

Batch	A				B			
Drum No.	2		6		1		8	
Button No.	1	2	1	2	1	2	1	2
Replicate Impressions	115	120	124	116	133	128	137	124
	119	124	124	127	131	124	132	136
	123	117	129	125	131	138	125	130
	114	124	130	122	136	130	127	121
	117	126	113	115	132	130	135	117
Mean	118	122	124	121	133	131	131	126

20 kg. was near to the minimum load yielding sensibly constant hardness values. A load of 30 kg. is therefore preferable as it is less likely to be affected by aberrations in the preparation of the surface. In different I.C.I. laboratories, 20 kg. and 30 kg. loads have been used without confusion, but the 30 kg. load has now been standardised for the sake of uniformity. At the hardness level of interest, this gives a hardness figure about 1½ points lower than the 20 kg. load. Since this decrease in hardness is found on pickled as well as unpickled surfaces, it is clearly unconnected with the decrease which results from the removal of the hardened layer by pickling. The fact that the two are equal is fortuitous, and does nor confirm the expected relation between the load and the sensitivity of the results to surface condition. With the scatter of results obtaining in all the measurements (see below) it is, of course, impossible to be dogmatic about 2 point differences from any reasonable number of tests.

The preferred procedure is therefore to prepare the flats down to 2/0 emery and carry out the test with 30 kg. load, which is applied for 15 seconds.

Reproducibility.—The inhomogeneity within and between buttons, which has already been commented upon, raises the questions of how many impressions should be made on a button and how many buttons should be tested in order to determine the mean hardness of a quantity of granules with adequate precision. In the hardness range of most interest, 110–150 D.P.N., and with optimum conditions of testing, the standard deviation of replicate impressions on a button is about 5 D.P.N., and the standard deviation of replicate buttons from a bulk lot of titanium, after allowing for within-button variation, is about 3 D.P.N.

By testing five impressions on each button, the contribution of the within-button variation to the over-all variation in mean button hardness becomes small compared with that of the between-button variation. Using this procedure the standard deviation of the mean button hardness is about 4 D.P.N.

The accuracy of estimation of the mean hardness improves as the square root of the number of buttons tested so that, for two buttons, the standard deviation of the estimate of hardness is about 3 D.P.N. This is considered adequate for routine evaluation. The normal procedure for routine evaluation is thus to obtain two test samples, prepare one button from each, and make five hardness determinations on each button. Under optimum conditions the over-all mean estimates the hardness of the granules to 95% confidence limits of about ± 6 D.P.N.

Converting from standard deviations to the more immediately comprehensible scatter of individual hardness readings, the average range of five readings on a button encountered is about 12 D.P.N., with occasional values up to 30 points, whilst the average difference

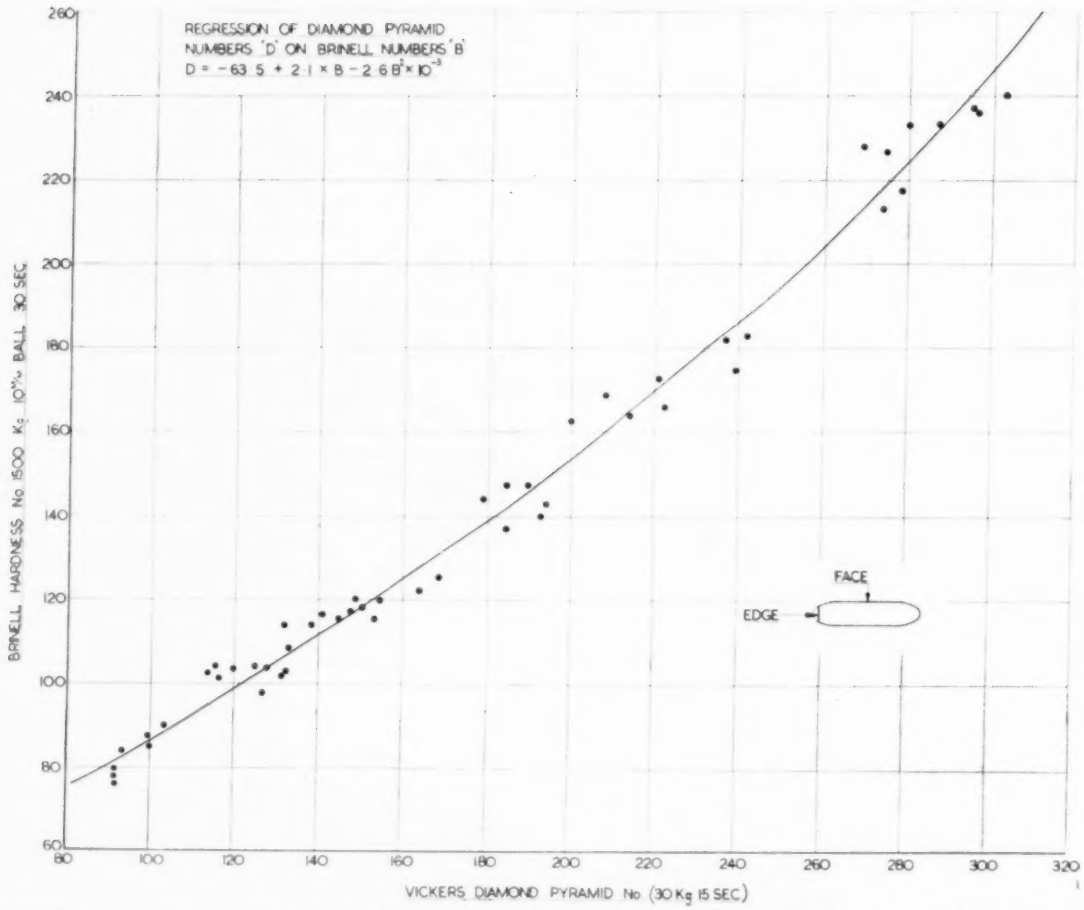

Fig. 5.—Relationship between Vickers diamond pyramid hardness numbers determined on edge of button and Brinell hardness numbers determined on face of button.

between mean values for replicate buttons is about 4 points, with occasional differences of up to 12 points. Table II gives some typical results obtained by an experienced operator in the course of routine evaluation in a laboratory melting 20–30 buttons per day.

It must be pointed out that the values given in Table II refer to random variations, and do not preclude the possibility of systematic error arising from the test procedure not being followed properly. They also do not allow for differences within and between laboratories, due, for example, to variations in hardness testing machines or to differences in the technique of reading the impressions. Experience over a long period has shown that the hardness evaluation of a sample, using two buttons, lies on 95% of occasions within ± 8 D.P.N. of the true figure, and the 95% confidence limits for the difference between the evaluations of two samples from one bulk lot are ± 12 D.P.N.

Correlation with Brinell.—If Brinell hardness is required it should, if at all possible, be determined directly. Circumstances arise, however, when it is necessary to convert existing D.P.N. values relating to material which is not available for test, and to permit this the correlation has been determined by carrying out both tests on some fifty buttons ranging in hardness from about 90 to 300 D.P.N. The Brinell test was done in duplicate on a flat on the face of the button using 10 mm. ball and 1,500 kg. load applied for 30 seconds, the diamond pyramid test on the edge as described and using 30 kg. load. The regression line of mean diamond pyramid on mean Brinell is shown in Fig. 5. Prediction of the results to be expected is subject to considerable uncertainty—for instance, over most of this curve the 95% confidence limit lines would be at least 20 points of either test apart—but the " best " line is reasonably well established.

REFERENCES.

1 v. Bolton, *Z. Elektrochem.*, 1905, **11**, 45.
2 Craighead, Simmons and Eastwood, *J. Metals*, 1950, **188**, 485.
3 Kohn, *J. Electrochem. Soc.*, 1952, **99**, 89.

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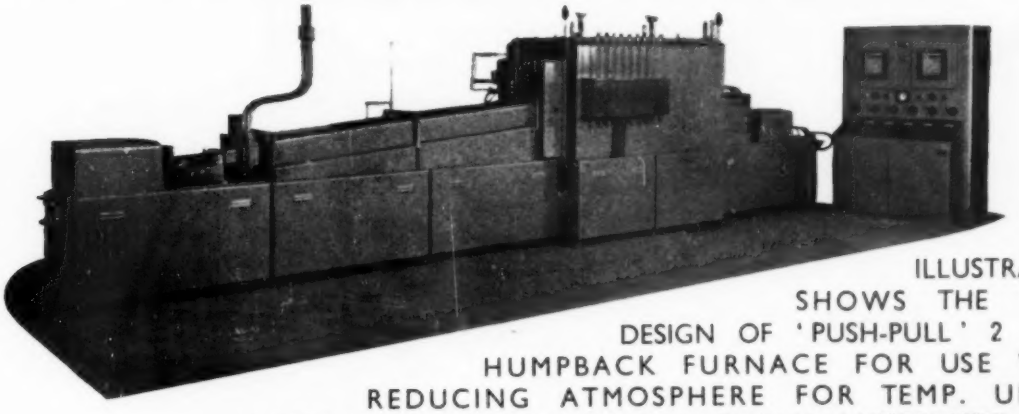

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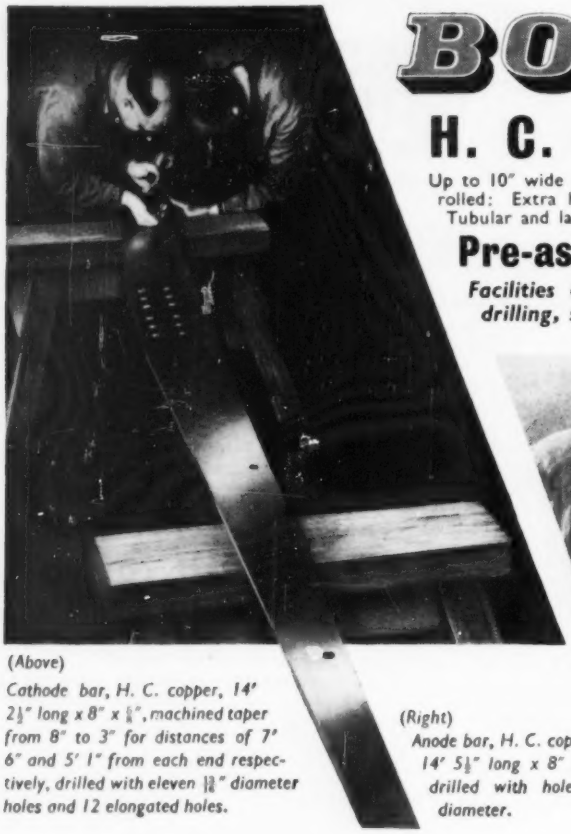

(Above)
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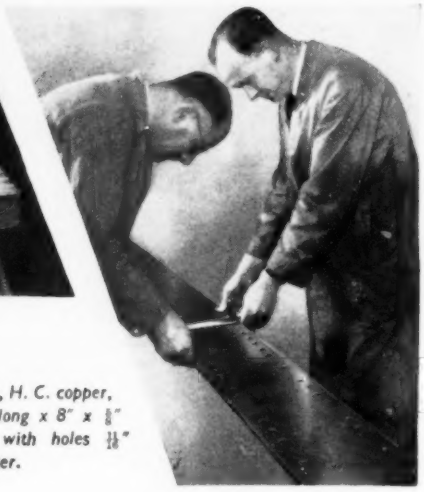

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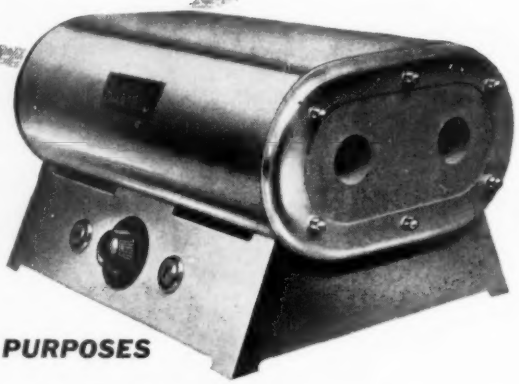

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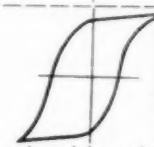

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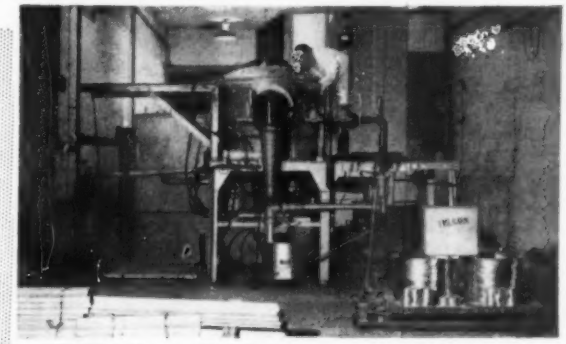

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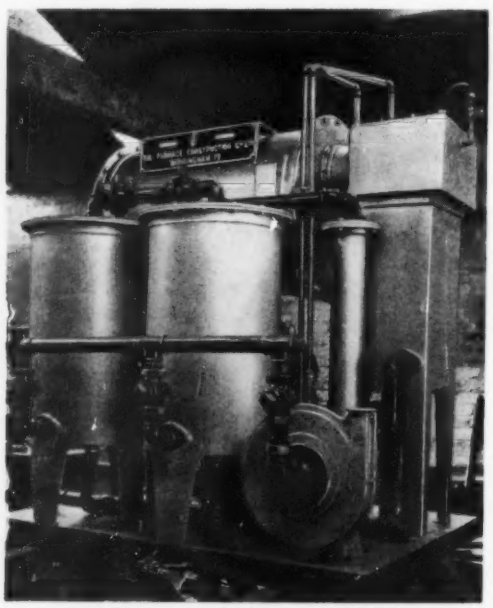

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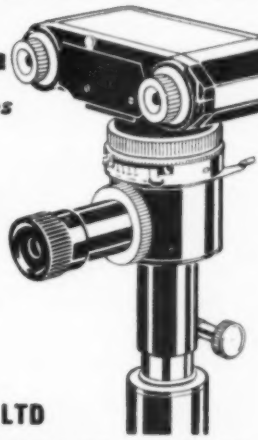

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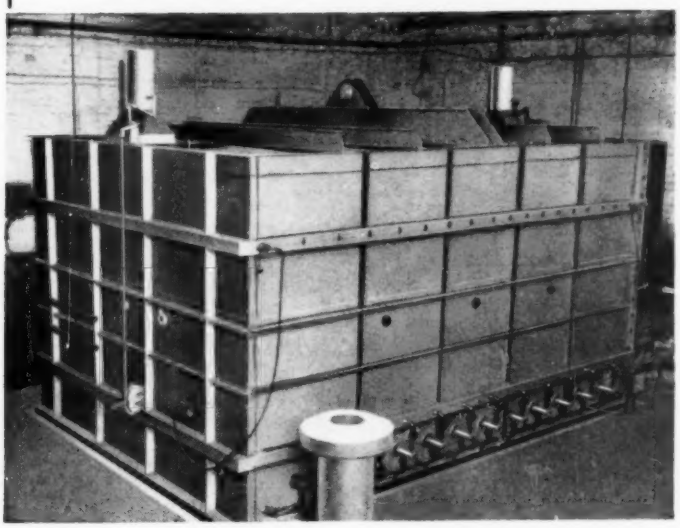

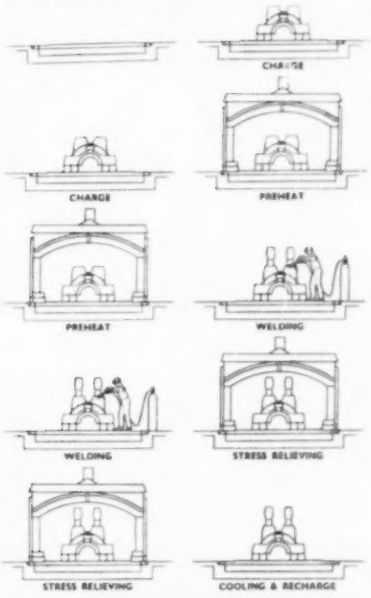

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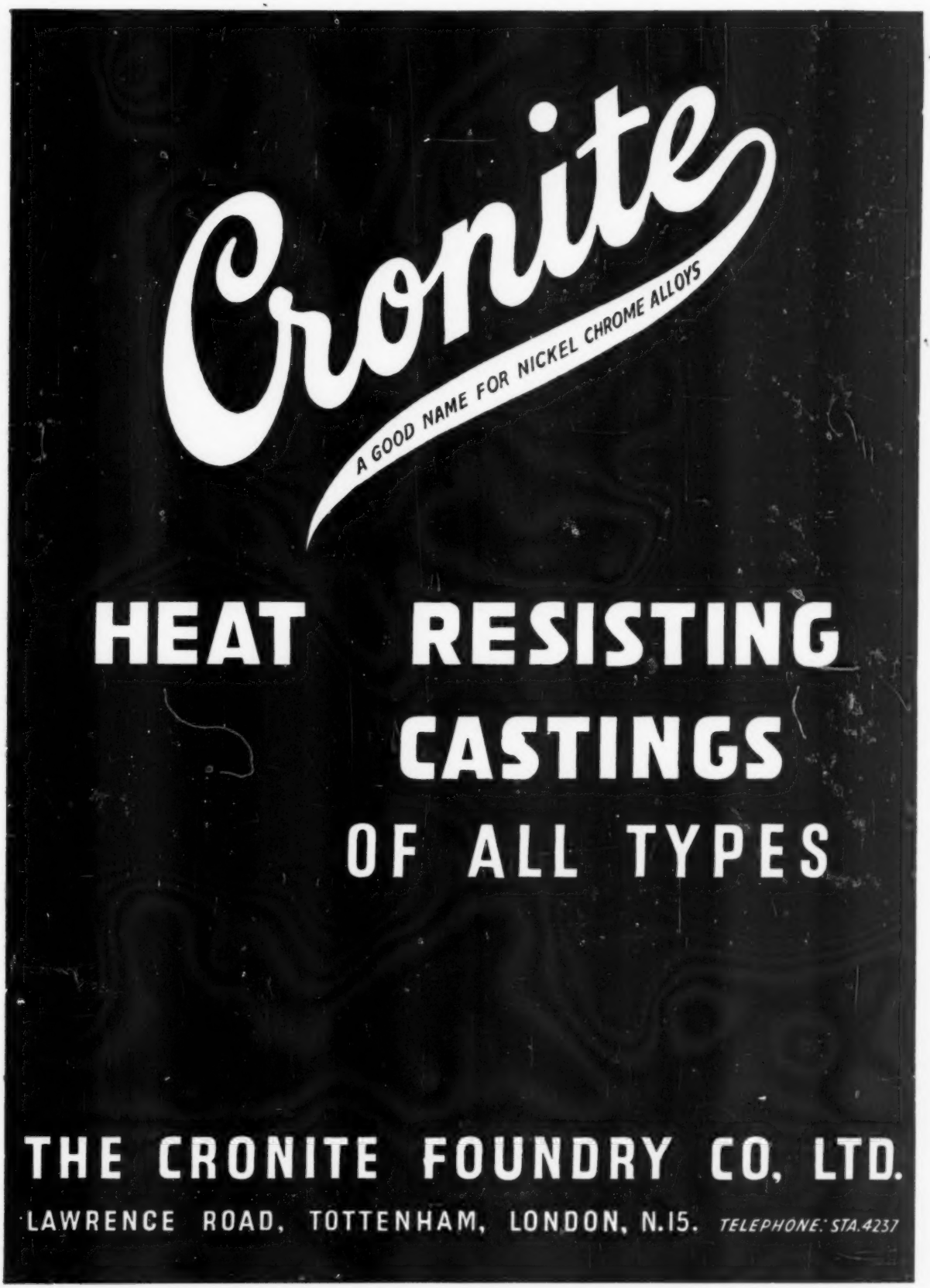
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